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Malnutrition and nutrient deficiencies: manifestations on oral health - Narrative review

Universidade Fernando Pessoa

Faculdade de Ciências da Saúde

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RESUMO

O fornecimento adequado de nutrientes, água, hidratos de carbono, proteínas, lípidos, fibras, vitaminas e minerais, é obrigatório não só para a manutenção da vida, mas também para manter o estado nutricional adequado e promover a saúde, nomeadamente a saúde oral. De facto, a saúde oral pode ser negativamente afetada pela malnutrição.

Esta revisão narrativa tem como objetivo investigar a associação entre a malnutrição e deficiências nutricionais específicas e as suas manifestações na saúde oral.

A desnutrição proteico-energética está associada à doença periodontal e, durante o desenvolvimento do organismo, pode levar a atraso na erupção dentária, à redução do tamanho dos dentes, à diminuição da solubilidade do esmalte e à disfunção das glândulas salivares. Nos idosos, a desnutrição proteico-energética pode causar sarcopenia e "disfagia sarcopénica", o que compromete a ingestão de nutrientes.

No que diz respeito à vitamina C, verificou-se que a sua deficiência está relacionado com a doença periodontal, a hemorragias gengivais e ao escorbuto; os efeitos orais comuns associados à carência de vitamina do complexo B incluem uma sensação de ardor na boca, nomeadamente na língua, lábios inflamados e gretados, inflamação das mucosas da cavidade oral e da língua, úlceras orais, queilose angular e dores de garganta; a carência de vitamina D pode contribuir para a progressão da doença periodontal e para a reabsorção dos ossos maxilares, e levar ao desenvolvimento do "dente raquítico".

Relativamente aos minerais, a inadequação de magnésio, cálcio e fósforo pode levar à perda prematura de dentes, ao enfraquecimento dos dentes e ao atraso na erupção dentária com hipoplasia do esmalte ou da dentina. A deficiência em flúor tem um impacto negativo na formação dos dentes e contribui para a cárie dentária.

Para além disso, a inadequação nas vitaminas A, B1, C e E, e nos minerais ferro, folato e fósforo, associou-se significativamente ao aumento da gravidade da doença periodontal.

Concluiu-se que existem ligações profundas entre a nutrição e a saúde oral, e as deficiências nutricionais podem ter repercussões significativas na cavidade oral. O médico dentista tem um papel fundamental a desempenhar na deteção dos sinais orais e dentários das várias

formas de malnutrição.

Reforçar os conhecimentos nesta área e capacitar os médicos dentistas com conhecimentos sobre a associação de deficiências nutricionais e problemas de saúde oral, pode ajudar a melhorar a qualidade de vida dos doentes, defendendo uma saúde oral óptima, ao mesmo tempo que combate a malnutrição e as deficiências nutricionais.

Palavras-Chave: desnutrição, proteínas, vitaminas, minerais, oligoelementos, açúcar, doença periodontal, cárie dentária

ABSTRACT

The adequate supply of nutrients, water, carbohydrates, proteins, fats, fibre, vitamins and minerals, is mandatory not only to sustain life, but also to maintain the adequate nutritional status and to promote health, namely oral health. In fact, oral health can be negatively affected by malnutrition.

This narrative review aims to investigate the association between malnutrition and specific nutritional deficiencies and its manifestations on oral health.

Protein-Energy undernutrition is associated to periodontal disease, and during the body's development can lead to delayed tooth eruption, reduced tooth size, decreased enamel solubility, and salivary gland dysfunction. In the elderly, Protein-Energy undernutrition can cause sarcopenia and "sarcopenic dysphagia," which compromises the intake of vital nutrients.

In what concerns vitamin C, its deficiency was found to be linked to periodontal disease, gingival bleeding and scurvy; common oral effects associated with vitamin B-complex deficiency include a burning sensation in the mouth, particularly on the tongue, inflamed and cracked lips, inflammation of the mucous membranes of the oral cavity and tongue, oral ulcers, angular cheilitis and sore throat; vitamin D deficiency can contribute to the progression of periodontal disease and jawbone reabsorption, and lead to the development of the 'rickets tooth',

Regarding minerals, inadequacy of magnesium, calcium, and phosphorus can lead to premature tooth loss, loosened teeth, and delayed dental eruption with enamel or dentin hypoplasia. Deficiency in fluorine has a negative impact in the formation of teeth and contributes to dental caries.

Moreover, inadequacy of the vitamins A, B1, C and E, and of the minerals iron, folate and phosphorus were significantly associated with increased severity of periodontal disease.

Profound connections exist between nutrition and oral health, and nutritional deficiencies can have significant repercussions on the oral cavity. The dentist has a key role to play in detecting the oral and dental signs of the various forms of malnutrition.

Strengthening knowledge in this area and empowering dentists with knowledge regarding the association of nutritional deficiencies with oral health problems, can help improve the quality of life of patients by advocating for optimal oral health, while combating malnutrition and nutritional deficiencies.

Keywords: undernutrition, protein, vitamin, mineral, trace-element, sugar, periodontal disease, dental carie

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LIST OF ACRONYMS AND ABBREVIATIONS

AAs	Amino Acids
g/kg	Gram Per Kilogram
mg/day	Miligram per Day
ng/mL	Nanogram per Mililiter
nmol/l	Nanomolar per Liter
ROS	Reactive Oxygen Species
WHO	World Health Organization
µM	Micromolar

I. INTRODUCTION

Nutrition is a fundamental aspect of human growth and development, and involves the examination of the impact of food and nutrients on the body. The adequate supply of the various nutrients: water, carbohydrates, proteins, fats, fibre, vitamins and minerals, is mandatory not only to sustain life, but also to maintain the adequate nutritional status and to promote health. There is also a strong association between nutrition and oral health (Gondivkar et al., 2019).

The definition of good oral health involves the absence of oral-facial pain, mouth or throat cancer, infections, mouth sores, periodontal diseases, caries, tooth loss, and other diseases and disorders that restrict the proper functioning of the stomatognathic system, which includes the ability to bite, chew, smile, and speak (Tenelanda-López, Valdivia-Moral and Castro-Sánchez, 2020). In addition, dental diseases must be considered when evaluating oral health, and can have a detrimental effect on a person's self-confidence and quality of life (Gondivkar et al., 2019).

On one hand, oral health can be negatively affected by malnutrition. Malnutrition is the state where the body does not present an adequate amount of the essential vitamins, minerals, and other nutrients required to sustain healthy tissues and organ functions (Sheetal *et al.*, 2013).

Malnutrition can occur due to insufficient nutrients supply or disease and can affect the growth and development of orofacial structures, as well as increase the risk of periodontal disease, oral mucosal disease, and dental diseases. Morever, it has been shown that a person's nutrition and diet can affect the development and integrity of the oral cavity and the installation and progression of oral diseases. On the other hand, compromised oral health can affect a person's ability to consume a healthy diet, potentially leading to a decline in their nutritional status and in their oral health. In fact, clinical and epidemiological studies have shown that diet, nutrition, and the condition of the mouth are intertwined for a lifetime, both in health and illness. The relationship between oral health and nutrition is multifaceted, meaning that diseases affecting the mouth, including infectious diseases, as well as acute, chronic, and systemic diseases with oral manifestations, can negatively impact a persons' ability to eat and consequently their nutritional state (Touger-Decker and Mobley, 2013; Gondivkar *et al.*, 2019).

Conversely, it has been demonstrated that following an "optimal oral health diet," which is rich in fruits, vegetables, and in vitamins C and D, dairy calcium, and other essential nutrients, and low in simple carbohydrates, can help decrease inflammation of the gingiva and of the risk of periodontal tissue (Luo *et al.,* 2018).

For these reasons, a diagnosis linking the oral condition to nutritional status is essential and should be of interest to health professionals, particularly dentists, dieticians and nutritionists. A report by the Institute of Medicine intitled "Improving Access to Oral Health Care for Vulnerable and Underserved Populations" highlights the importance of training and educating health professionals to merge advice on oral health with counselling on diet and lifestyle. The report also emphasizes that a healthy diet plays a crucial role in maintaining good oral health. On the contrary, literature extensively demonstrates that malnutrition and specific nutritional deficiencies neagatively affect oral health. Additionally, the World Health Organization acknowledges the obligation of both oral health care professionals and dietetics practitioners in promoting oral health and considers that diet and nutrition play a role in preventing oral diseases and improving oral health (Touger-Decker and Mobley, 2013).

2. Methodology

To conduct this study, a literature review was carried out using the PubMed and Google Scholar databases. The search terms used included malnutrition, oral health, oral diseases, nutritional deficiencies, vitamins, minerals, and proteins. The search was conducted between January and June 2023, using various combinations of search terms to focus the information on the specific topic: nutritional deficiency, malnutrition, oral health and oral pathologies.

Inclusion criteria were applied to limit the search to articles published in English and French within the last 15 years. Afterwards, articles were selected based on a review of their title and abstract, with any articles that did not align with the topic being excluded

After a thorough search and analysis, a total of 42 articles were directly related to the study's purpose and were deemed relevant to the present research.

II. DEVELOPMENT

1. Definition and origins of malnutrition

i. Malnutrition and nutritional deficiencies: definitions and causes

Diet and nutrition are essential for maintaining the general and oral health of populations. The term "diet" refers to the total food intake of individuals and can be influenced by factors such as environmental conditions, food availability, religious beliefs, socioeconomic status, and more. Many health conditions such as obesity, diabetes, heart disease, various types of cancer, osteoporosis, and both oral and dental problems can be avoided by following a well-planned and nourishing diet. This "healthy diet" consists of a variety of different foods that provide adequate amounts of nutrients needed to maintain good health and balance in what concerns energy. Nutrition involves the process of using food for growth, metabolism, and tissue repair, encompassing activities like eating, digesting, absorbing, transporting, incorporating nutrients into cells, and eliminating residue. There is a mutually influential relationship between oral health and nutrition and diet. Oral infections, as well as acute, chronic, and systemic diseases with oral symptoms, affect the ability to eat and, consequently can lead to insufficient diet and nutrient inbalance. Similarly, nutrition and diet can impact the development and the condition of the mouth and the progression of oral diseases (Zohoori, 2020).

The term "malnutrition" refers to deficiencies, excesses or imbalances in an individual's energy and/or nutritional state. (WHO, 2021).

The term encompasses three main categories:

1. Undernutrition, which can be defined as “inadequate supply of energy, protein or other nutrients necessary for the maintenance and repair of tissues. Usually, this condition occurs due to inadequate food intake and / or increased energy and / or nutritional needs” (White *et al.*, 2012), and includes:

Wasting (low weight/height ratio), which is often a sign of recent and severe weight loss resulting from inadequate food intake and/or infectious diseases such as diarrhoea, which lead to weight loss. (WHO, 2021).

Stunting (low height/age ratio), which is the result of chronic or recurrent undernutrition generally associated with multiple factors such as unfavourable socio-economic conditions, poor maternal health and nutrition, frequent illnesses and inadequate feeding and care practices for infants and young children. Stunted growth prevents children from reaching their full physical and cognitive potential. (WHO, 2021).

Underweight (low weight/age ratio).

It deserves to be highlighted that wasting and stunting are particularly deleterious and more common in under-five-year-old children. A child who is underweight may be stunted, wasted or both. (WHES, 2023).

2. Micronutrient-related malnutrition, which includes inadequate intake of essential vitamins and minerals or excessive consumption of micronutrients (WHO, 2021).

3. Overweight, obesity and non-communicable diseases linked to dietary factors, including cardiovascular disease, stroke, diabetes and certain types of cancer (WHO, 2021).

The term undernutrition typically implies a decrease in nutritional intake as the primary cause. However, there are instances where undernutrition or deficiencies in energy or in specific nutrients can develop even when intake is normal or higher than normal, which can be attributed to three main factors (Elia, 2017):

Malabsorption of nutrients that can lead to undernutrition. **Excessive nutrient loss** that can occur due to conditions like prolonged diarrhea and high-flow intestinal fistulas, which can significantly increase sodium requirements or result in significant protein losses, such as with extensive exudative burns. **Increased metabolic demands** associated with certain diseases or conditions. For instance, extensive burns can elevate total energy requirements, while inflammatory conditions can raise the need for specific antioxidant nutrients such as vitamin C that may be catabolized and be excreted more rapidly than usual due to excessive free radicals generated by the underlying disease. In all of these situations, a "normal" intake of nutrients is insufficient because it fails to compensate for the losses or increased needs resulting from the underlying disease (Elia, 2017).

ii. Socio-economic and environmental factors that contribute to malnutrition and nutritional deficiencies

In developed countries, the main concerns related to malnutrition are:

- Overweight, obesity and associated diseases, resulting from excessive consumption of energy, sugars and fats;
- Disease-related undernutrition, which is caused by a concomitant disease and characterized by the presence of inflammation (Cederholm *et al.*, 2019).

Conversely, developing countries face the opposite problem, where hunger and insufficient energy and nutrients consumption remains a prevalent problem, leading to high rates of disease, mortality and severe nutrient deficiencies. Although excessive malnutrition is traditionally associated with developed countries, epidemics of obesity and diabetes, conditions partly attributed to overnutrition, are spreading rapidly to developing countries, often surpassing their capacity to cope with excessive consumption (Baudin, 2014).

Regarding the prevalence of these conditions related to nutritional status, in 2014, around 462 million adults worldwide were underweight, while 1.9 billion adults were classified as overweight or obese. In 2016, an estimated 155 million children under the age of 5 years old were stunted, whereas 41 million were overweight or obese. Undernutrition is the cause of circa 45% of deaths in children under 5 years old, mainly in low- and middle-income countries. Paradoxically, these countries are also witnessing an increase in rates of overweight and obesity among children (WHO, 2021).

Many factors can contribute to hunger and undernutrition. These include armed conflict, climate change, limited access to clean water, economic shocks and inequality, all of which can lead to food insecurity in vulnerable communities (ACLF, 2020).

Food insecurity occurs when people do not have constant access to a sufficient quantity of safe and nutritious food to ensure their normal growth, development and general well-being. Food insecurity manifests itself in several levels. People with moderate food insecurity experience uncertainty about access to food and may be forced to compromise other basic necessities in order to meet their dietary needs. In general, they are content to consume readily available or affordable foods, which are not necessarily the most nutritious. This trend is contributing to an increase in obesity and various forms of malnutrition. Processed foods

high in energy, saturated fat, sugar and salt are often more affordable and accessible than fresh fruit and vegetables. Although these foods can help meet daily energy needs, subjects in this situation may still lack the vital nutrients needed to maintain optimal health and adequate bodily functions . When a person suffers from severe food insecurity, it means that they have exhausted their food reserves and have gone without food for a day or more. In fact, they are probably suffering the effects of hunger.(FAO, 2023).

Food insecuity, and consequently undernutrition, can arise due to several causes:

Conflicts have a direct impact on food security by seriously compromising people's ability to access food: people are often forced to flee, lose their livelihoods and food distribution channels may be disrupted. Natural disasters, such as droughts, cyclones and floods have increased over the last three decades and can be attributed to the effects of climate change. In-depth United Nations research in more than 40 developing countries reveals that declining agricultural production, directly or indirectly influenced by climate change, is likely to significantly increase the prevalence of hunger in the coming years. Insufficient access to drinking water is also a major factor contributing to the emergence of undernutrition. According to the World Health Organisation (WHO), around half of all cases of child undernutrition can be directly attributed to the consumption of contaminated water (ACLF, 2020).

Poverty is closely linked to food insecurity and increases the risk and consequences of undernutrition. Moreover, people with limited means are more likely to suffer from various types of malnutrition. In addition, undernutrition increases health costs, reduces productivity and impedes economic progress, thus contributing to a damaging cycle of poverty and poor health. Malnutrition, in its various manifestations, has an impact on every nation in the world. The fight against malnutrition in all its forms represents a crucial challenge for global health. (WHO, 2021).

2. Effects of nutrients deficiencies on oral health

i. The effects of protein deficiency on oral health

Protein is a vital macronutrient in a well-balanced diet, and is essential for growth, muscle strength and function, immune function, wound healing, and overall tissue homeostasis. In addition to general health, dietary protein plays an essential role in maintaining oral health by acting as a foundational element for bone and the periodontium, as well as contributing to tissue regeneration (Kotronia *et al.*, 2021; Jayasinghe *et al.*, 2022).

Proteins are made of various amino acids (AAs), linked by peptide bonds. There are twenty-one AAs, including non-essential AA, essential AA, which must be obtained from the diet, and branch-chain AAs. Multiple AAs are required to form a protein. Dietary protein come from non-animal, meaning plant food, such as legumes, cereals and nuts, and animal products such as meats, eggs, and milk sources. Several chemical indices determine the quality of a protein, but the bottom line is the ratio of essential to non-essential AAs and digestability. Protein from animal sources is complete, meaning that provides all essential AAs, whereas most plant sources provid incomplete protein, lacking one or more essential AAs, and therefore should be combined in order to allow protein synthesis (Jayasinghe *et al.*, 2022).

The recommended daily intake of protein is 0.8 g/kg body weight, although for elderly adults (≥ 65 years old), experts in the field of protein and aging recommend a protein intake between 1.2 and 2.0 g/kg of body weight per day (Baum, Kim and Wolfe, 2016).

Protein-Energy undernutrition occurs when there are deficiencies in protein, energy-rich foods, or both, relative to the body's requirements. The deficiencies in dietary energy and protein typically occur together. Such a state of undernutrition during the body's development can have effects on oral structures, including delayed tooth eruption, reduced tooth size, decreased enamel solubility, and salivary gland dysfunction (Sheetal *et al.*, 2013).

Protein-Energy undernutrition is also frequently observed in the elderly population. A prevalent outcome is the development of sarcopenia, a condition characterized by the decline of muscle mass, strength, and functionality. Consequently, sarcopenia can negatively affect swallowing abilities, leading to a condition known as "sarcopenic dysphagia," which

compromises the intake of vital nutrients (Azzolino *et al.*, 2019).

On the contrary, increased consumption of protein is linked to enhanced recovery of periodontal tissues and favorable oral functionality (Kotronia *et al.*, 2021; Jayasinghe *et al.*, 2022).

Besides the amount of protein, it is crucial to take into account the AA composition of proteins on its influence on oral health. Amino acids have various effects on oral tissues, many of which are advantageous. They work by diminishing the colonization of oral tissues by bacteria, regulating the inflammatory response to alleviate gingivitis and mucositis, lowering the risk of dental decay by enhancing saliva's ability to neutralize acids or maintain mineral balance, and influencing the immune system to promote the phagocytosis of bacteria. Amino acids have diverse roles in promoting oral health. For instance, L-arginine was found to inhibit bacterial coaggregation in the oral cavity, effectively preventing plaque formation. It was also observed that L-arginine monohydrochloride regulates the development and composition of multi-species oral biofilms, while enhancing the effectiveness of cetylpyridinium chloride, an antimicrobial compound. Additionally, lower levels of histidine in adolescents aged 12-15 years appear to be associated with an increased risk of dental caries (Jayasinghe *et al.*, 2022).

ii. The effects of vitamin deficiency on oral health

Vitamins are a heterogeneous collection of essential organic compounds that are crucial for growth, development, human health and well-being. These compounds are directly involved in important metabolic pathways, vital for surviving since they act as catalysts for metabolic reactions that involve proteins, fats, and carbohydrates, and are therefore essential for energy production, growth, development and cell maintenance. Despite the fact that only small quantities of these compounds are needed daily, they play an essential role in facilitating millions of physiological processes, which makes them remarkable agents. Vitamins are divided into two groups based on their solubility in water or lipids. Vitamins A, D, E, and K are fat soluble, while B-complex vitamins and vitamin C are water-soluble. Deficiencies in these compounds affect overall health and an imbalance in these compounds can lead to malnutrition. Moreover, its deficiency also has a direct or indirect impact on oral health (Shaik and Pachava, 2017).

a. Vitamin C

Vitamin C, also known as ascorbic acid, is a vital water-soluble antioxidant for the body. It also serves as a specific cofactor in many enzymatic reactions, which are essential for the synthesis and maintenance of collagen. Humans are unable to produce this vitamin on their own and its body storage is limited, and therefore vitamin C must be obtained from diet. The daily requirement of vitamin C varies according to age, gender, pregnancy and breastfeeding. The recommended amount of vitamin C is 90 mg/day for adult men and 75 mg/day for adult women, with an upper limit of 2000 mg/day (Murererehe *et al.*, 2022).

Fresh vegetables, such as broccoli, green and red peppers, tomatoes, green leafy vegetables, cauliflower and cabbage, are important sources of vitamin C, whereas vitamin C-rich fruits include oranges, pineapples, papayas, raspberries, lemons, strawberries, cherries, cantaloupes, grapefruits and watermelons. Although in lower concentration, potatoes are also a source of vitamin C (Abdullah, Jamil and Attia, 2022).

Periodontal disease and vitamin C deficiency have been found to be linked through scientific research. The ability of vitamin C to promote periodontal healing is associated with its antioxidant properties and its role in the synthesis of collagen, wich is essential for wound healing. Gingival bleeding can occur even in good oral hygiene due to a lack of vitamin C. Studies have found that people with lower intake of vitamin C (≤47.34 mg/day) are more susceptible to severe periodontal disease than those with higher intake (>132.2 mg/day). Subjects suffering from periodontal disease can benefit from vitamin C supplements, which were shown to reduce inflammation (Tada and Miura, 2019; Murererehe *et al.*, 2022).

Insufficient synthesis of collagen can also result in scurvy when plasma levels of vitamin C drop below 10 μM. Scurvy is characterized by symptoms such as bleeding gums, poor wound healing and increased tooth mobility due to the weakening of collagen that forms the periodontal ligament. Other manifestations of scurvy include anemia, fatigue, depression, and, in the most severe cases, death (Ngo *et al.*, 2019).

Additionally, chewing gum containing vitamin C has been found to help to prevent tartar build-up in healthy individuals. Vitamin C may also play an important role in preventing the development of dental caries (Eydou *et al.*, 2020). Indeed, Vitamin C induces calcium

deposition, mineralisation and may reduce the risk of developing secondary caries in children (Shaik and Pachava, 2017).

Vitamin C is also thought to have the power to prevent carcinogenesis (Ngo *et al.*, 2019), and is currently recommended as a therapeutic measure to decrease the possible carcinogenesis and progression of oral cancer (Murererehe *et al.*, 2022).

b. B-complex Vitamins

The group of essential water-soluble vitamins, excluding vitamin C, is collectively known as Vitamin B-complex. They work as coenzymes and are obtained primarily through dietary intake (Ali *et al.*, 2022). This group includes thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pantothenic acid (vitamin B5), pyridoxine (vitamin B6), biotin (vitamin B7 or B8), folic acid (vitamin B9), and cobalamin (vitamin B12). While vitamin B complex is necessary for cell growth and metabolism, each member of the group has a distinct structure and performs unique functions. Vitamins B1, B2, B3, and biotin are involved in different aspects of energy production, vitamin B6 is crucial for amino acid metabolism, and vitamin B12 and folic acid aid in the necessary steps for cellular division (Varela-López *et al.*, 2018).

Although a healthy diet should provide a sufficient supply of B-complex vitamins, recent evidence indicates that some groups, such as children or pregnant women, may have high requirements for one or more B-complex vitamins. This can lead to an increased risk of deficiency with varying impacts on human health depending on the severity of the deficiency (Ali *et al.*, 2022).

One of the impacts of inadequate vitamin B-complex intake is the affection of oral structures. Common oral effects associated with vitamin B-complex deficiency include a burning sensation in the mouth, particularly on the tongue, inflamed and cracked lips, inflammation of the mucous membranes of the oral cavity and tongue, oral ulcers, cracks in the corners of the mouth (angular cheilitis) and sore throat (Sheetal *et al.*, 2013).

Thiamine, also referred to as **Vitamin B1** or aneurin, is crucial for the metabolism of proteins, fats, and carbohydrates. It is predominantly present in organ meats, pork, nuts, and legumes, as well as in unprocessed cereals, grains, starch roots, and tubers (Zohoori, 2020).

Vitamin B1 deficiency may lead to oral manifestations such as hypersensitivity of the oral mucosa, glossitis, loss or impairment of taste, tiny herpes-like vesicles on the oral mucosa, under the tongue and erosion of the oral mucosa. In relation to dental caries, a deficiency of cocarboxylase or thiamine triphosphate, may contribute to tooth decay by causing a build-up of pyruvic acid in tissues. In addition, thiamine consumption has been associated with a reduction in caries due to thiamine's ability to inhibit the growth of cariogenic microorganisms (Shaik and Pachava, 2017).

Riboflavin, also known as **Vitamin B2**, is a water-soluble fluorescent form of flavin with a heat-resistant ribitol side chain. Riboflavin occurs in nature in two forms: riboflavin-5′-phosphate and riboflavin-5′adenosyl-disphosphate. It is found mostly in animal organs such as the liver and kidney, as well as yeast extracts. This vitamin can also be found in dairy products, eggs, beef, and wheat bran. The vitamin is required for the breakdown of lipids, ketones, carbohydrates, and proteins. Although deficiency is rare nowadays, it can occur in certain populations, such as the elderly or subjects suffering from alcoholism. Riboflavin insufficiency has been linked to seborrhoeic follicular keratosis of the brow and nose, anogenital dermatitis, and severe light sensitivity with ocular vascularisation (Gossweiler and Martinez-Mier, 2020).

In what concerns oral health, vitamin B2 deficiency can lead to oral glossitis and angular cheilitis (Shaik and Pachava, 2017).

Vitamin B3, also known as **Niacin**, comprises two separate vitamins, nicotinic acid and nicotinamide, which is a natural derivative. Both are found in food and good sources of niacin include red meat, fish, wheat flour, eggs and milk (NHS, 2020).

Deficiency of niacin is the primary cause of pellagra, characterized by the presence of dementia, dermatitis and diarrhoea. If untreated can lead to death. This vitamin deficiency may have oral features such as glossitis, gingivitis and stomatitis (Thomas and Mirowski, 2010).

Vitamin B6, often referred to as **pyridoxine**, refers to three distinct forms of the vitamin: pyridoxine or pyridoxol - alcohol group, pyrodoxal - aldehyde group, and pyridoxamine - amine group. Pyrodoxal and pyridoxamine in their phosphorylated forms are abundant in lean meats, fish, eggs and dairy products. Unprocessed whole grains, yeast extracts, potatoes, bran, germ and various vegetables, on the other hand, are rich in pyridoxol. Pyridoxine deficiency

is more common in alcoholic subejcts and can cause recurrent mouth ulcers, halitosis, severe gingivitis, tongue pain and pigmentation, cheilitis (Gossweiler and Martinez-Mier, 2020) and increases the likelihood of developing cavities (Shaik and Pachava, 2017).

Biotin is present in foods at relatively low levels. However, royal jelly and brewer's yeast are two exceptions that contain significant amounts of biotin. In addition, biotin is present in its protein-bound form in organ meats such as liver, egg yolks, some grains and nuts such as oilseeds and alfalfa, dried soybeans, and peanuts. Its free form can be found in vegetables, green plants, fruits, milk, and rice bran. A biotin deficiency may cause a range of symptoms, including fatigue, nausea, dry and scaly skin, anemia, high levels of serum cholesterol, periorificial dermatitis, conjunctivitis, hair loss, loss of muscle coordination, and developmental delay (Gossweiler and Martinez-Mier, 2020).

In what regards oral health, it may increase the risk of developing caries (Shaik and Pachava, 2017).

Vitamin B9, **folate** or **folic acid**, is a broad term used to describe this type of vitamin. Folate occurs in organ meats like liver, broccoli, Brussels sprouts, spinach, asparagus, peas, chickpeas and fortified breakfast cereals. An inadequate intake of folate can put you at risk of developing megaloblastic anaemia due to a folate deficiency (NHS, 2020).

Oral clinical manifestations of vitamin B9 deficiency are burning of the tongue and buccal mucosa, a red and swollen tongue, and angular cheilitis (Thomas and Mirowski, 2010).

Vitamin B12 or **cobalamin** is general term used to describe all cobalamins that have anti pernicious anemia properties. Sources of vitamin B12 in the diet include meat and fish (which contain adenosyl- and methylcobalamin), dairy products (mostly hydroxocobalamin, particularly in milk), canned meat and fish (sulphitocobalamin), egg whites, cheese, and haddock (cyanocobalamin) (Gossweiler and Martinez-Mier, 2020).

Vitamin B12 deficiency can lead to pernicious anaemia, which results in structural oral symptoms such as a bright red, painful and burning tongue due to atrophic glossitis (Shaik and Pachava, 2017).

c. Vitamin D

Vitamin D is a collection of fat-soluble hormones that impact the body's ability to absorb calcium, magnesium, and phosphate in the intestine. Its main forms are D2 (ergocalciferol) and D3 (cholecalciferol), which differ in their side-chain structures. This vitamin can be obtained through food but foods containing vitamin D are not common and it is found naturally only in fatty fish such as salmon, mackerel and herring, and in fish oils such as cod liver oil. The main natural source is the synthesis of vitamin D from cholesterol in the skin via exposure to ultraviolet B rays from the sun. On its turn, 1,25-dihidroxicholecalciferol (or calcitriol) is produced when vitamin D is hydroxylated and plays a major role in regulating calcium and phosphate concentrations for bone growth and remodelling, being therefore essential for the mineralization of bones and teeth. Additionally, recent studies have shown that calcitriol is also important in regulating immune and inflammatory responses (Ebersole *et al.*, 2018).

The concentration of 25(OH)D3, the hydroxylated form of vitamin D3 and the most stable form of vitamin D in the plasma. Therefore, it determines the amount of vitamin D in the body, which generally ranges from 25 to 138 nmol/l. A concentration below 37.5 nmol/l indicates vitamin D deficiency. Vitamin D deficiency is mainly caused by insufficient exposure to ultraviolet B rays from the sun, but can also be due to insufficient dietary intake of vitamin D or to genetic disorders affecting absorption and metabolic conversion (Botelho *et al.*, 2020).

Vitamin D deficiency can lead to a decrease in bone mineral density and increase the likelihood of developing osteoporosis, as well as contributing to the progression of periodontal disease and jawbone reabsorption (Jagelavičienė *et al.*, 2018).

In dental cells, a lack of vitamin D signalling pathways combined with low levels of calcium and phosphate ions can lead to poor tooth mineralisation and defects in mineralisation, to problems with calcification of dentin and also predentin, and ultimately to malformation of the dentin. Low levels of vitamin D can lead to the development of the 'rickets tooth', which is a weakened and poorly mineralized organ that is highly susceptible to decay. Morevoer, severe vitamin D deficiency, with levels below 10 ng/mL, can lead to low calcium and phosphate levels in the body, a condition known as hypocalcaemia and hypophosphataemia (Botelho *et al.*, 2020).

Both men and women with periodontitis tend to have lower vitamin D levels than those without, with a higher difference between women with periodontitis and healthy women: healthy subjects present levels of 22 ng/ml, whereas these levels fall to 18 ng/ml in sick women and to 20 ng/ml in sick men (Ebersole *et al.*, 2018).

There is also some evidence to suggest that vitamin D deficiency may play an important role in the development and progression of certain types of oral cancer, although further research is needed to fully understand this association. It is interesting to note that patients with oral neoplastic lesions are more likely to be vitamin D deficient. Therefore, it is important that future studies examine the relationship between vitamin D deficiency and the development of oral cancer, as well as the potential therapeutic benefits of vitamin D in combination with anti-cancer drugs (Botelho *et al.*, 2020).

On the other hand, a vitamin D concentration of at least 75 nmol/L has been associated with lower rates of dental caries in children (Botelho *et al.*, 2020).

Adequate vitamin D intake may help reduce the risk of chronic periodontitis and gingivitis through its anti-inflammatory, immunomodulatory and antiproliferative effects, as well as its ability to induce cell apoptosis. In addition, vitamin D plays a crucial role in bone metabolism and in the prevention of tooth loss, and it can enhance the antibacterial defences of gingival epithelial cells, improve wound healing after periodontal surgery and reduce gingival inflammation. Therefore, vitamin D supplementation is useful in periodontal prophylaxis (Jagelavičienė *et al.*, 2018) .

iii. The effects of mineral deficiency on oral health

Similarly to vitamins, the body needs minerals in modest amounts. These nutrients are necessary for normal physiological functions and metabolic activity, such as the development of bones and teeth, the preservation of human tissues and fluids, the maintenance of normal nerve function, and they also act as building blocks in enzyme systems. Macrominerals and microminerals (trace elements) make up the majority of the minerals the body needs, with macrominerals having a requirement of about 100 mg/day, whereas trace elements are required in small quantities of about 15 mg/day. Minerals and trace elements can be found in various food sources such as meat, cereals, fish, milk and dairy foods, fruits, vegetables and

nuts (NHS, 2020).

The relation of diet minerals and oral health is narrow since the primary structural elements of the tooth are minerals found in the diet, namely magnesium, calcium and phosphorus. These minerals play a significant role in strengthening teeth and preventing decay. On the contrary, minerals deficiencies result in impaired absorption, increased bleeding propensity, bone resorption, looseness, and early tooth loss. They are also associated to hypoplastic enamel or dentin, as well as delayed tooth eruption. Calcium deficiency leads to fragile dental enamel, which is unable to fend off the acids that cause tooth decay. It is also important to hightlight that minerals found in teetth work in tandem, reducing enamel loss and decay and promoting jawbone strength. Inadequate dietary intake of magnesium, calcium, and phosphorus can lead to premature tooth loss, loosened teeth, and even delayed dental eruption with enamel or dentin hypoplasia. Recent research has shown that magnesium, rather than calcium, plays a more significant role in enamel remineralization, helping to resist decay by promoting the formation and growth of hydroxyapatite crystals. A calcium-rich diet without sufficient magnesium may result in soft enamel that is susceptible to decay (Uwitonze *et al.*, 2020).

In what regards trace elements, their deficiency may cause various clinical outcomes as each element is linked to multiple enzyme systems. Deficiencies can affect general health as well as oral health, as trace elements play a direct or indirect role in maintaining oral health (Shaik and Pachava, 2017).

Fluorine, a trace element, is essential for the formation of teeth and bones, along with calcium, phosphorus, and magnesium. Fluorine can be obtained through food and water intake, but dental use of fluorine helps to maintain oral health and to prevent conditions by reducing enamel solubility, increasing enamel resistance to demineralizing acids, remineralizing carious lesions, and decreasing bacterial plaque growth (Braeckevelt, 2022).

This is why topical fluoride, administered through toothpastes, gels, foams and varnishes, has been used as a preventive strategy against tooth decay. In view of its beneficial functions, fluoride has been incorporated into various dental restorative substances such as glass ionomers. These substances act as reservoirs that can distribute fluoride in the mouth and replenish their fluoride content when fluoride is present in toothpaste, mouthwash or fluoride-enriched foods (Najeeb *et al.*, 2016).

However, excessive fluoride levels during the teeth calcification stage can also lead to dental fluorosis, which can range from small white patches to severe tooth mottling. The intensity of the effect is determined by several factors, including the fluoride content in drinking water, the state of calcification of the teeth at the time of exposure, as well as the duration and amount of exposure (Bhattacharya, Misra and Hussain, 2016).

In what concerns the role of minerals in dental caries, Navia has proposed a preliminary categorization of mineral and trace elements into five groups based on their potential to increase or decrease caries:

- caries promoting elements include selenium, magnesium, cadmium, platinum, lead, and silicon;
- mildly cariostatic elements are molybdenum, vanadium, strontium, copper, boron, lithium, and gold;
- elements with uncertain effects on caries are beryllium, cobalt, manganese, tin, zinc, bromine, and iodine; caries-inert elements are barium, aluminum, nickel, iron, palladium, and titanium; and
- strongly cariostatic elements include fluorine and phosphorus (Shaik and Pachava, 2017).

The possible oral health negative effects arising from nutrient deficiencies, but also attributed to specific nutrients or to their excess, highlight the importance of a healthy balanced diet (Gondivkar *et al.*, 2019).

iv. The effects of sugar on oral health

Carbohydrates are the main source of dietary energy for human populations, accounting for 55-75% of total daily energy requirements. They are mainly found in plant foods, such as cereals, legumes, fruits, but also in dairy products. These nutrients are made up of carbon, hydrogen and oxygen and are traditionally divided into two groups according to their structure and speed of digestion: simple carbohydrates, which are rapidly digested, and complex carbohydrates, which are digested more slowly. In humans, carbohydrates play a crucial role in the production and storage of energy. Glucose, a type of simple carbohydrate, is the preferred source of energy for several types of cells, including those in the brain and in

the blood. If the diet lacks carbohydrates or fats, the body can break down proteins to produce glucose, which can be avoided by eating carbohydrates. Glucose is also needed to prevent the onset of ketosis, a metabolic state that occurs when the liver produces ketone bodies from fatty acids (Zohoori, 2020).

Sugars are known as being by far the most significant dietary element in the development of dental caries, and the biology of the process of enamel dissolving brought on by acid fermented sugar compounds produced by bacteria is well understood (Sheiham and James, 2014).

In this sense, one should distinguish between:

Natural sugars found in whole fruits, vegetables, grains, and milk, do not appear to contribute significantly to the development of dental caries or other noncommunicable diseases. This is because of natural food properties such as fiber content, water content, and protective substances such as polyphenolic chemicals or calcium. Furthermore, fruits, vegetables, and cereals help to counteract the potential negative effects of these sugars by mechanically stimulating salivary flow. The WHO, on the other hand, considers all other sugars to be 'free sugars', which include monosaccharides and disaccharides added to foods by manufacturers, food handlers, or customers, as well as those found naturally in honey, syrups, fruit juices, and concentrates. The use of free sugars should be restricted for health reasons. In 2002, an expert consultation on diet, nutrition, and the prevention of chronic diseases organized by the World Health Organization and Food and Agriculture Organization advised limiting the consumption of free sugars to no more than 10% of total energy requirements. Furthermore, the WHO has proposed a conditional recommendation to reduce free sugar intake to less than 5% of total energy requirements (Moynihan and Kelly, 2014).

The intake of soft drinks is a known risk factor for dental caries. These beverages usually contain significant amounts of simple sugars, such as glucose, fructose, sucrose and other monosaccharides. When these sugars are fermented by oral bacteria, they release acid that corrodes tooth enamel, leading to cavities. Therefore, the consumption of sweetened beverages may increase the risk of dental caries, with the likelihood of this outcome increasing with the frequency and quantity of consumption of these beverages (Kumar *et al.*, 2014).

Moreover, sugar and carbohydrates have not only been connected to an increased incidence of

dental caries, but they have also been linked to gingival bleeding. Sugar consumption is associated with an increased incidence of gingival bleeding, according to seven controlled investigations. Even dental hygienists and dentistry students, who are assumed to have high oral hygiene habits, were shown to present increased gingival bleeding as a result of consuming more sweets (Hujoel and Lingström, 2017).

3. Common Conditions associated with malnutrition and nutritional deficiencies in oral health

Micronutrient and macronutrient intake have an effect on the dental hard tissues as well as the oral mucosa. Both under- and over-nutrition have a variety of effects on dental health. (Gondivkar *et al.*, 2019).

i. Periodontal diseases

Periodontitis is an inflammatory condition of the supporting tissues of the teeth that results from specific microorganisms or groups of microorganisms, leading to progressive destruction of the periodontal ligament and alveolar bone, accompanied by the formation of increased probing depth, recession, or both. Failure to treat this condition may lead to the gradual loss of teeth and of alveolar bone. According to estimates, periodontitis affects 40% to 90% of the global population, making it one of the most widespread epidemics in the world. The primary microorganisms involved in periodontal diseases include the red-complex bacteria *Porphyromonas gingivalis, Prevotella intermedia, Tannerella forsythia, and Treponema denticola.* Additionally, *Fusobacterium nucleatum, Prevotella species, Eikenella corrodens, Peptostreptococcus micros, and Campylobacter rectus* have also been detected in periodontal pockets (Najeeb *et al.*, 2016).

Periodontitis primarily affects the gums, causing inflammation, bleeding, and swelling after infection. Its classification is based on the severity of infection and gum condition and divided into different stages:

Gingivitis, the initial stage, is characterised by red, swollen gums that can be treated with appropriate medical and oral care. Without proper care, it can progress to a more severe form

that affects deeper layers of the gum and jawbone, resulting in the formation of pus in the gingival pocket and causing halitosis or bad breath. This form is called **periodontitis**. **Aggressive periodontitis** is a severe and advanced form of gingival infection that can lead to tooth loss, making chewing difficult and affecting overall dental function, and ultimately nutritional status and global health. Generalised aggressive periodontitis is characterised by rapid destruction of gingival tissues and bone, while localised aggressive periodontitis remains confined to specific dental surfaces (mainly first molars and incisors) with a high rate of bone resorption progression (Ray, 2023).

Periodontal tissue destruction is triggered by the release of inflammatory factors from immune cells, which attract polymorphonuclear leukocytes to the site of infection. When stimulated by bacterial antigens, these leukocytes produce reactive oxygen species (ROS), enzymes, and defensins that eliminate pathogens during phagocytosis. However, ROS also harm healthy tissues by damaging Deoxyribonucleic Acid, DNA, and producing cytokines from macrophages and monocytes. Reactive oxygen species may also activate osteoclasts, the cells responsible for bone resorption, leading to periodontal tissue destruction. Diseased periodontal tissues contain higher levels of ROS compared to healthy tissues, owing to oxidative tissue damage. The treatment of periodontitis involves the removal of the underlying factors such as dental plaque, microbial biofilm, and calculus by scaling and root planing, complemented by oral hygiene instructions. Poor oral hygiene resulting in dental plaque formation containing microorganisms is the primary cause of periodontitis. Apart from these local factors, various systemic factors like diabetes, cardiovascular disease, and pregnancy have also been linked to periodontitis (Najeeb *et al.*, 2016).

A deficiency in proper nutrition has also been identified as a major contributing factor to the development of periodontal disease. The exact pathway by which poor nutrition leads to periodontal disease is not fully understood, but it is known that nutritional factors can influence the inflammatory response, and deficiencies can exacerbate this response. Inadequate intake of vitamin A, B1, C and E, iron, folate and phosphorus were significantly associated with increased severity of periodontal disease. Conversely, research has shown that a diet high in fruits, vegetables, dairy, vitamin C and D, calcium, and other nutrients, and low in simple carbohydrates, can help to reduce gingival and periodontal inflammation. It is believed that this mechanism operates by modulating the inflammatory response (Luo *et al.*, 2018).

In fact, it has been demonstrated that dietary antioxidants, such as vitamin C, protect the periodontium from the damaging effects of free radicals, ROS, and reactive nitrogen species (Ray, 2023). A previous analysis of National Health and Nutrition Examination Survey, NHANES, dataset revealed an inverse association between total antioxidant levels and periodontal disease (Luo *et al.*, 2018).

As previsously presented, vitamin C is essential for the production of collagen and serves as a scavenger for ROS, protecting against oxidative damage. An in vitro study has shown that applying locally a magnesium salt containing vitamin C can improve collagen synthesis and reduce ROS-induced inflammation in gingival fibroblasts. A clinical trial by Shimabukuro et al. demonstrated that a dentifrice containing vitamin C and magnesium salt can effectively reduce gingival inflammation. Compared to conventional dentifrice, the vitamin C-containing dentifrice has shown to exhibit significantly higher anti-ROS activity (Najeeb *et al.*, 2016).

The intricate connections between nutrition and inflammation are still being explored, but it is evident that inadequate nutrition is linked to an elevated likelihood of developing periodontal disease (Luo *et al.*, 2018).

ii. Dental caries

Dental caries is the process of mineral loss from tooth structure and the most common chronic disease in the world, affecting people throughout their lives in both developed and low-income countries. The Global Burden of Disease 2010 study indicates that oral diseases affect 3.9 billion people, with untreated caries on permanent teeth being the most common condition, with a global prevalence of 35% across all age groups. This condition can cause pain, discomfort and anxiety. If left untreated, it can lead to the spread of infection and, ultimately, tooth loss. Sugars are widely recognised as the main dietary factor contributing to the development of dental caries (Sheiham and James, 2014; Hagman *et al.*, 2021), which can be easily understood considering the biological steps of caries formation: the demineralisation of enamel and dentine is due to the presence of organic acids produced by the bacterial activity of dental plaque, notably *mutans streptococci* and *lactobacilli*, which are fed by the anaerobic decomposition of dietary sugars. Demineralisation occurs when these organic acids increase the solubility of the calcium hydroxyapatite present in dental tissue. The development of caries depends on the presence of sugars and bacteria, but is also influenced

by factors such as tooth sensitivity, bacterial composition, the quantity and quality of saliva and the length of time fermentable carbohydrates are available for bacterial fermentation (Sheetal *et al.*, 2013; Takahashi *et al.*, 2017).

Dental caries can occur in both deciduous and permanent teeth, but newly erupted teeth are particularly vulnerable to decay. In addition, teeth with gengival recession are more susceptible to root caries. While nutritional status can affect teeth in the pre-eruptive phase, the impact of eating habits on the development of caries becomes crucial once the teeth have erupted. Enamel hypoplasia, characterised by underdeveloped enamel, can be attributed to deficiencies in vitamin A, vitamin D and protein-energy malnutrition. In addition, protein-energy malnutrition and vitamin A deficiency can lead to atrophy of the salivary glands, resulting in reduced salivary flow and buffering capacity, compromising the cleansing and acid-neutralising functions of saliva. Moderate deficiencies in protein, vitamins, zinc and iron can alter the protective properties of saliva. Combined with the increased frequency and quantity of sugar consumed, these deficiencies contribute to the increased risk and progression of caries (Gondivkar *et al.*, 2019).

III. DISCUSSION

There are clear and harmful connections between malnutrition and nutritional deficiencies and oralhealth, including the state of the teeth. Table 1 summarizes the oral health consequences arising from each nutrient deficiency previously presented.

Table 1. Nutritional deficiency and oral health consequences.

Nutritional deficiency	Oral health consequences
Protein-energy undernutrition	Cell regeneration and healing difficulties Amelar hypoplasia Increased susceptibility to the development of periodontal disease Delayed tooth eruption Reduced tooth size Salivary gland atrophy Increased risk of dental caries
Vitamin C	Delayed wound healing Candidiasis Gingival inflammation, gingival haemorrhage, cyanotic gingival tissue Leukoplakia Defective collagen formation Irregular dentin formation Periodontal disease
Vitamin B1	Reduced sensitivity to taste Burning sensation in the oral cavity Cracked lips Angular cheilosis Increased risk of dental caries
Vitamin B2	Glossitis Angular cheilitis Atrophy of the filiform papillae Ulcerative gingivitis
Vitamin B3	Glossitis Stomatitis Ulcerated gums Loss of filiform and fungiform papillae Glossodynia Atrophy of the salivary glands
Vitamin B6	Periodontal disease Stomatitis Glossitis Angular cheilitis Glossodynia Halitosis Increased risk of dental caries
Vitamin B9	Burning tongue and buccal mucosa Red and swollen tongue Angular cheilitis
Vitamin B12	Glossitis Stomatitis Oral ulceration

	Dysgeusia Leukoplakia Hemorrhagic gingivitis, Detachment of periodontal fibers
Vitamin D	Hypoplasia amelaris Difficulty in healing Increased risk of caries lesions Loss of alveolar bone in the lamina dura Increased risk of periodontitis
Calcium	Increased risk of caries lesions Increased susceptibility to the development of periodontal disease Hypomineralization Compromised tooth integrity Delayed eruption pattern
Magnesium	Premature tooth loss Delayed dental eruption
Phosphorus	Premature tooth loss Delayed dental eruption
Fluoride	Increased incidence of dental caries May interfere with teeth integrity

(Sheetal *et al.*, 2013; Murererehe *et al.*, 2022; Shaik and Pachava, 2017; Thomas and Mirowski, 2010; Jagelavičienė *et al.*, 2018; Uwitonze *et al.*, 2020).

As shown in the table above, and considering the available literature, nutritional deficiencies exert several influences on oral tissues and increase the risk of oral and dental diseases. Nutrient deficiencies have an impact on the formation of the oral cavity and on the development of oral health problems, by disturbing tissue balance, reducing resistance to microbial biofilms and altering tissue regeneration capacity (Zohoori, 2020).

Inadequate levels of vitamin D, as well as protein-energy undernutrition, have been associated with enamel hypoplasia. In addition, protein-energy undernutrition and B-complex vitamins deficiency are linked to atrophy of the salivary glands, which reduces the oral cavity's ability to fight infection and buffer acid plaque. Moderate nutritional deficiencies in proteins and vitamins can restrict the protective functions of saliva by altering its content and volume. Combined with a higher daily consumption of sugar, in terms of frequency and quantity, these deficiencies unequivocally contribute to an increase in the incidence and development of dental caries (Gondivkar *et al.*, 2019).

Deficiencies of B-complex vitamins have an impact on oral health. A common oral manifestation of insufficient levels of B-complex vitamins is a burning sensation in the mouth, particularly on the tongue. Other oral indications include chapped and reddened lips, inflammation of the mucous membrane of the oral cavity and tongue, mouth ulcers, angular cheilitis and a sore throat (Sheetal *et al.*, 2013).

Insufficient levels of calcium and of vitamins D, B-complex and C can lead to hypomineralisation, delayed tooth eruption, bleeding gums, impaired alveolar bone development, angular cheilitis and periodontal disease. Insufficient dietary intake of magnesium, calcium and phosphorus is generally linked to tooth mobility and premature tooth loss (Uwitonze *et al.*, 2020).

Finally, although lack of fluoride has no effect on mucous membranes, it is linked to a higher rate of dental caries (Thomas and Mirowski, 2010).

Hence, numerous oral conditions and oral mucosa abnormalities are associated with nutrient deficiencies. Nevertheless, there is limited awareness regarding the essential role of dentists in the comprehensive care of patients with oral health problems and the impact of the nutritents of the diet on oral health (Kavitha, Vivek and Hegde, 2011).

The oral mucous membranes exhibit clinical signs of nutrient deficiencies early on, primarily due to the rapid turnover of most oral mucosal cells, typically occurring within a span of 3 to 7 days. Clinical observation by the dentist is important because it can provide initial indications following the detection of nutritional deficiencies. Nevertheless, it is essential to note that solely relying on clinical observations is insufficient for establishing a definitive deficiency diagnosis. A comprehensive assessment that includes a thorough health and dietary history, along with clinical and biochemical examinations, is imperative. In some cases, additional diagnostic tests may be required to arrive at a precise differential diagnosis. Oral health experts can include dietary and nutritional aspects in oral health assessments and integrate dietary considerations into educational conversations. For people whose oral health condition affects their eating ability or nutritional well-being, oral health professionals can provide basic interventions to assess dietary and nutritional risks, educate patients about the relationship between diet and oral health and, in cases requiring in-depth nutritional assessment and dietary advice, refer patients to dietitians for medical nutrition therapy. Similarly, dietetic education and training should be rejuvenated, with an emphasis on interdisciplinary education and training that encompasses oral health and associated conditions. Awareness of the interaction between oral health, diet and nutrition should be promoted in health education programmes and in clinical practice (Touger-Decker and Mobley, 2013).

Therefore, it should be highlighted that collaborative groups of general practitioners, dentists,

nurses, dieticians and nutritionists working in tandem can, in this way, help to ensure that patients maintain both their oral health and receive adequate nutrition. These multidisciplinary teams are more capable of acting once oral problems are detected, and treat nutritional imbalances, leading to better outcomes in what regards oral and dental health, and nutritional status (Gondivkar *et al.*, 2019).

IV. CONCLUSION

General and oral health are closely linked to diet. There are many factors that contribute to the onset of malnutrition.

Profound connections exist between nutrition and oral health, and nutritional deficiencies can have significant repercussions on the oral cavity. They can contribute to a range of oral health problems, from dental caries to periodontal disease and damages to the oral mucosa, like glossitis, stomatitis or cheilitis

The dentist has a key role to play in detecting the oral and dental signs of the various forms of malnutrition. Moreover, muldisciplinary teams of general practitioners, dentists, nurses, dieticians and nutritionists may ensure adequate treatment for these oral and dental problems.

The dentist, through the clinical signs observable in the mouth, can be the first to identify manifestations of malnutrition. While remaining within their field of expertise, dentists can provide their patients with personalised recommendations or refer them to a nutrition expert, such as a nutritionist or dietician.

In conclusion, this research underscores the imperative need for heightened awareness regarding the significance of nutrition in oral health, coupled with interdisciplinary training for dentists to enhance early detection, prevention, and treatment of these intricate health concerns. Strengthening knowledge in this area and empowering dentists with knowledge regarding the association of nutritional deficiencies with oral health problems, can help improve the quality of life of patients by advocating for optimal oral health, while combating malnutrition and nutritional deficiencies.

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