Journal of Applied Pharmaceutical Science Vol. 0(00), pp 001-022, 2024
Available online at
DOI: http://doi.org/10.7324/JAPS.2024.1704606786
ISSN 2231-3354

Aspects of nutriment in maintaining gum wellbeing: A literature review

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ARTICLE HISTORY

Received on: 01/01/2024
Accepted on: 09/02/2024
Available Online: XX

Key words:
Chronic inflammatory process, macronutrients, dentistry, preserving, periodontal health, vitamins, trace elements, micronutrients, nourishment, perspective.

ABSTRACT

This is an exhaustive narrative review on nutritional importance regarding periodontium health. Macronutrients have a significant impact on oral health. Highly refined carbohydrate intake has been linked to dental cavities and periodontal diseases. In contrast, complex carbohydrates in whole grains and vegetables promote periodontal health. Proteins are essential for host defenses and the synthesis of connective tissues, making them crucial for periodontal well-being. Vegetable proteins positively affect periodontal health. Dietary fats promote inflammation and increase the risk of periodontal disease. Omega-3 fatty acids are well-known for their anti-inflammatory properties and minimizing periodontal inflammation. Vitamins and minerals are essential in maintaining periodontal health. Vitamins A, D, and K are necessary for oral epithelial integrity, bone growth, and tissue maintenance. Ca^{2+} and Mg^{2+} deficiencies have been associated with severe periodontal diseases. Antioxidants like vitamin C can mitigate periodontal inflammation. Most dental practitioners acknowledge that a person's nutritional status attenuates periodontal disorders. The severity of inflammation in the gums is indirectly impacted by the inherent resistance of the periodontal tissues to infection at a systemic level. Dental professionals should address local irritants through different procedures, promote daily plaque control at home, and offer nutritional counseling on improving overall periodontal health.

INTRODUCTION

A wholesome (balanced) diet epitomizes excellent physical condition [1] and often leads to healthy buccal health and a beautiful smile (Fig. 1) [2,3]. A vital aspect of long-term health, growth, and metabolic consequences in the deterrence and therapeutic intervention of disease hinges on nutrition [4–6]. Nutrition is the biochemical and physiological activity by which living creatures utilize food components [7] to sprout, mature, sustain themselves, and reproduce [7,8]. The influence of nutrition on the body's tissues and organs exists locally and systemically [9–11]. Nutrition strongly affects the integrity of the periodontium [12,13].

The availability of a sufficient supply of essential nutrients to the host significantly impacts the viability of the periodontal tissues in both health and disease [14,15].

Nutrients are generally categorized into micronutrients, macronutrients, and essential nourishments [16]. A range of nutrients can significantly influence periodontal health [12,17]. Macronutrients comprise proteins, lipids, and carbohydrates,

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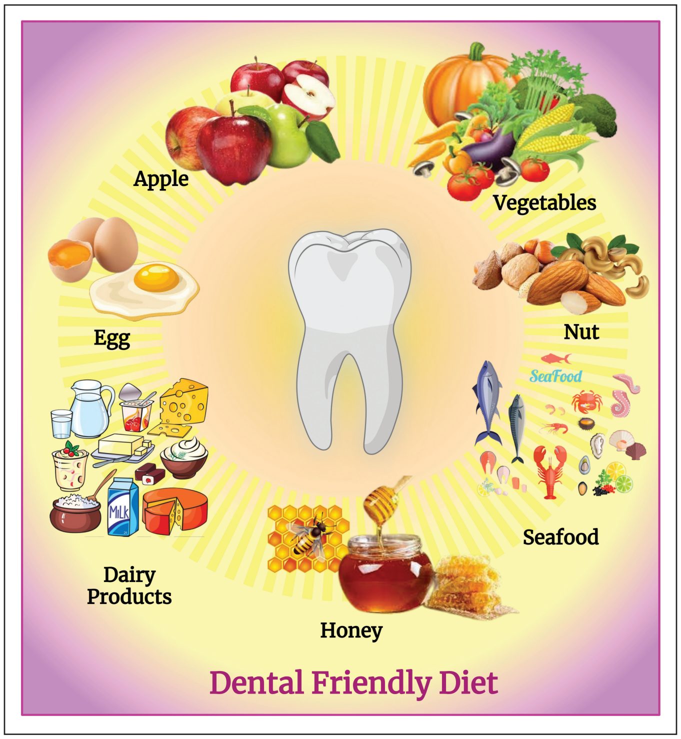

Figure 1. Schematic representation showing dental, especially periodontal-health-friendly diets. This figure has been drawn with the premium version of BioRender (https://biorender.com/ accessed on 30th December 2023) with the license number NX269Y56XP. Image Credit: Susmita Sinha.

indispensable nutrition constituents [18]. However, micronutrients include water and fat-soluble vitamins, trace minerals, minerals, and organic acids, frequently necessitated to conserve vital physiological functions [19]. Essential nutrients are biological molecules and embrace selected amino and fatty acids, sterols, and vitamins [20]. Essential nutrients are expressed as those that cannot be produced or are insufficiently made from the beginning by animals, including human beings, to accommodate their physiological need [16].

Micronutrients are the constituents of food that are needed in small or negligible quantities [21,22]. Carotenoids and carotene (vitamin A), ascorbic acid (vitamin C), tocopherol (vitamin E), folate and folic acid (vitamin B9), iron, zinc, copper, phosphorus, calcium, glutathione, quercetin, tannic acid, N-acetyl cysteine (NAC), and melatonin are typical examples of micronutrients and trace elements and act as antioxidants [23–26]. If not consumed at the apposite level, these micronutrients are often reported to provoke inflammatory disorders in periodontal tissues [17,21,27–29].

In concomitance with oxygen and water, macronutrients such as minerals, proteins, carbohydrates, and fats must be consumed appropriately [30]. High carbohydrate (HC) [31], especially sugar-sweetened beverages [32,33], saturated fat with low fiber [17,34], and scarce protein, vitamin C, and B12 [35–37] consumption has been attributed to gingival bleeding, gingivitis dental cavities, periodontal disease, overall poor oral health [17,38].

Typical cellular metabolism yields reactive oxygen species (ROS). After that, ROS performs several physiological activities [39]. Nevertheless, excessive synthesis of ROS starts exhibiting injurious or pathological outcomes by oxidizing nucleic acids such as deoxyribonucleic acid (DNA), lipid peroxidation, protein carbonylation, and ultimately infuriating tissue impairment, including cellular aging and death [40–42]. Multiple studies reported that periodontal disorders generate ROS in very high amounts from inflammatory cells. The extra quantity of ROS diffuses out and ultimately damages vital organs, causing systematic diseases, such as cataracts, malignancy, and cardiovascular disease [43]. It also denotes individuals suffering from chronic periodontitis possess threatened antioxidant competence [44–48]. It has been reported that ROS increases osteoclast growth while suffering from periodontal disorders, leading to growth deterioration of maxillary and mandibular bone, thereby damaging periodontal anatomy and loss of tooth [49,50].

It has been reported that antioxidants' pharmacodynamic properties possess the potential to alleviate the irreparable teeth-supportive anatomical mutilation triggered by unrestrained amounts of ROS [44,51,52]. Antioxidants' pharmacological potential includes several vibrant belongings [53]. Free radicals neutralizing molecules scavenge free radicals and confiscate changeover metal ions, disintegrating hydrogen peroxide or hydroperoxides. It also extinguishes operational pro-oxidants and augments endogenic antioxidant protection; nevertheless, it repairs damaged cells through ROS [54,55].

Antioxidants archetypally differed principally into two forms: endogenous and exogenous [56,57]. Endogenous antioxidants signify that these molecules can be formed by the human body [58]. Common endogenic enzymatic antioxidant particles include "superoxide dismutase, catalase, glutathione peroxidase, and reduced glutathione or glutathione-reductase" [59–62].

Endogenous antioxidants, accompanied by vitamins and minerals, are the most functional and competent enzymatic set-up at odds with oxidative stress under physiological equilibrium [63,64]. Exogenous antioxidants denote that the human system is incompetent to produce these molecules of their own. They are usually naturally derived from fruits, vegetables, meat, and fish. These days, exogenous antioxidants are manufactured in laboratories [65,66]. Frequently utilized exogenous antioxidants are "ascorbic acid (vitamin C), tocopherol (vitamin E), quercetin, tannic acid, and NAC" in dental issues [51].

PROBLEM STATEMENT OF THE STUDY

The research question evaluates the effect of micronutrient and macronutrient fortification on periodontal parameters in healthy people with healthy periodontium.

OBJECTIVES OF THE STUDY

This review's primary objective is to assess micronutrients' impact on periodontal health by consulting the accessible substantiation from pertinent research results and inspecting the effect of different doses of micronutrients on periodontal health outcomes. To help formulate public strategies for public health workers, to restrict the gap between the prevailing scientific papers, and to highlight areas where further research is required.

MATERIALS AND METHODS

A wide-ranging literature review was steered to congregate applicable information on the impact of macronutrients and micronutrients on periodontal health. Databases such as PubMed and Scopus were systematically searched for articles published up to 2023. Key words included were “periodontal disease,” “macronutrients,” “micronutrients,” and specific nutrients such as carbohydrates, proteins, lipids, and vitamins A, D, E, K, C, B complex, and minerals. The articles included were based on their relevance to the connection between nutrition and periodontal health. Studies focusing on the impact of macronutrients and micronutrients on periodontal tissues were selected. Studies investigating dietary patterns, nutritional intake, and their association with periodontal diseases were prioritized (Fig. 2). Information regarding the recommended daily doses for various was also collected. Special attention was given to the quality of evidence, study designs, and methodologies for assessing the rapport concerning nutrients and periodontal health.

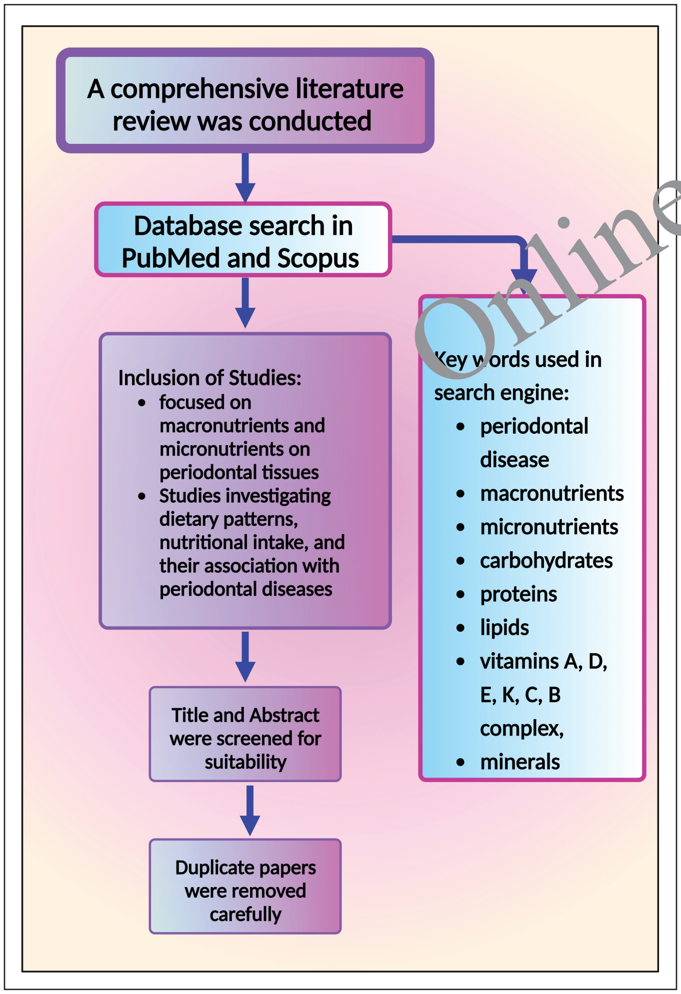

Figure 2. The materials and method section of the current study was portrayed. This figure has been drawn with the premium version of BioRender (https://biorender.com/ Accessed on 21st December 2023) with the license number BI268O2W3Q. Image Credit: Susmita Sinha.

IMPACT OF MACRONUTRIENTS ON PERIODONTAL DISEASE

Carbohydrates

Multiple studies reported no clear-cut or comprehensive explanation regarding the terms HC and low-carbohydrate (LC)-containing diet. This issue is raised as the paramount impediment to deducing the research findings. After that, the HC or LC diet is a comparative notion [67–71]. However, it has been broadly reported that it is considered an HC diet when an individual derives over 45% of total energy from carbohydrates [67–71].

Carbohydrates are a crucial energy resource and contribute to fat metabolism [72–74]. Incorporating low-glycemic, unprocessed, and fiber-rich complex carbohydrates containing phytochemicals such as fruits, whole grains, or coarsely milled grains, vegetables, and legumes into the diet is generally considered healthy. These foods possess conceivable anti-inflammatory and antioxidant assets [75–78]. Conversely, high-glycemic, processed, and low-fiber carbohydrates such as refined sugar, white wheat flour, and sugary drinks can potentially contribute to several chronic inflammatory diseases [79–81]. Diet, including fermentable carbohydrates, can impact oral biofilm composition and potentially contribute to evolving oral conditions such as dental caries and periodontitis [82–84]. Contrary to expectations, it has been noted that incorporating raw vegetables into one’s diet can positively impact periodontal health [17,31,85].

Chewing raw vegetables has been recognized for supporting natural oral detoxification processes, leading to reduced plaque accumulation on the tooth surface, decreased periodontal inflammation, and a lower risk of developing tooth decay. This practice can contribute to improved periodontal and dental health [17,86].

Recent evidence indicates that consuming high-glycemic foods on their own may contribute to increased inflammation through activating nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB), high-sensitivity C-reactive protein, and oxidative stress [87–89]. Thereby, causing bleeding of the gums, as well as an elevated risk of gingivitis and periodontitis [90–92]. On the other hand, a diet copious in complex carbohydrates, without a corresponding increase in overall energy intake, can potentially decrease the risk of gingivitis and periodontitis [12,91–94].

Carbohydrates, because of their numerous functions, are present in all life forms [95]. Carbohydrates make up most of the organic stuff on earth [96,97]. Carbohydrates provide fuels, energy reserves, and metabolic intermediaries [74,98,99]. Plants and bacteria have polysaccharides as structural components in their cell walls [100–103] (Fig. 3). One of the most prevalent organic chemicals in the biosphere is cellulose, the primary component of plant cell walls [104,105]. Ribonucleic acid (RNA) and DNA are constructed from nucleobases related to a phosphate sugar, which remains the mainstay [106]. Ribose and

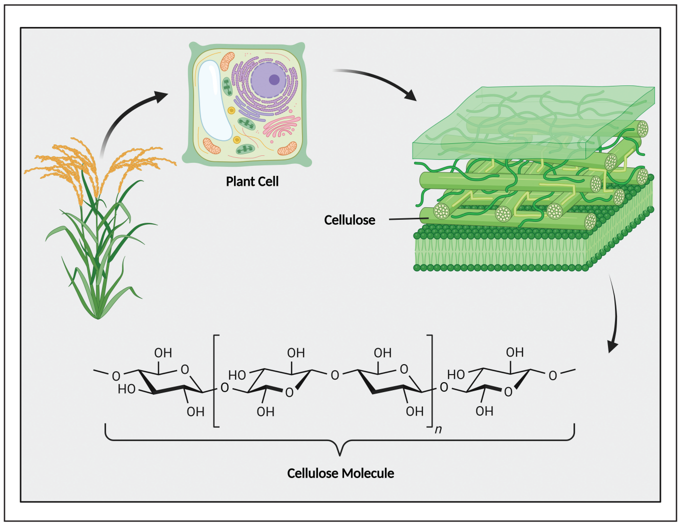

Figure 3. Schematic representation of cellulose chains in plant cell walls. This figure has been drawn with the premium version of BioRender (https://biorender.com/ accessed on 21st December 2023) with the license number EY268O3CFY. Image Credit: Susmita Sinha.

deoxyribose sugars form part of the physical skeleton of RNA and DNA, respectively [107,108].

Periodontal implication of carbohydrates

The presence of considerable portions of carbohydrates in individuals' diets, especially in the form of refined crystallized sugar and refined carbs (devoid of fiber, minerals, vitamins, and so on), encouraged microbioma (microbiome) dysbacteriosis (an imbalance in the microbiota community) in the buccal cavity. This oral dysbiosis possesses the ultimate potential to cause an inflammatory process, pursuing periodontal diseases with pocket formation extending severe clinical manifestation [109–112].

Glycosaminoglycans (GAGs) are exceedingly negative-charged polysaccharides (carbohydrates) constituted of reiterating disaccharide molecules [113]. GAGs are cataloged into four different clusters grounded on their carbohydrate remnants, such as hyaluronic acid (HA), chondroitin sulfate (CS), dermatan sulfate (DS), and heparan sulfate (HS), and keratan sulfate (KS) [114,115]. Thereby, carbohydrates are vital in synthesizing chondroitin, KS, and DSs and are essential for developing connective tissue components. After that, these molecules are extensively found on the cell membrane, in the extracellular matrix, and in connective tissue [116–118]. It has been reported that one of the chief extracellular matrix constituents is chondroitin sulfate proteoglycan (CSPG). CSPG performs an imperative role in organogenesis [119,120].

CS is involved in adding cells to dental tissue. CS furthermore determines the functional distinction of vital cells of the dental pulp. CS improves vascular cells, enhancing dental pulp tissue's restorative process after tooth damage [120].

Morquio syndrome [Mucopolysaccharidosis (MPS) type IV A)] is a sparse congenital (autosomal recessive) metabolic (lysosomal storage) disease instigated by the insufficiencies in the metabolism and dilapidation of unique enzymes named GAGs [121–125]. Morquio syndrome resulted in diverse continuing and long-lasting skeletal deformities. It also involves enamel defects of teeth and "broad mouth, unerupted, malposition, and spaced permanent teeth" [121]. The diagnosed cases of MPS between 1982 and 2009 were 1.53 per 100,000 live births were reported [126,127].

KS is considered the most novel GAG from the evolutionary perspective; little is known about this carbohydrate-derived new compound [128,129]. KS dispersed throughout the length of collagen (an unsolvable fiber composed of protein among all animals having a bony structure and vertebral column) fibrils in the predentin extracellular matrix to preserve constant texture. It has been reported that KS possesses properties to deflect collagen fibrillogenesis [130]. KS and other glycoproteins had a biological half-life ($t½$) of 6.8 days [131]. The principal action of proteoglycan GAGs, especially KS and CS, is tissue hydration and organization [128].

Proteoglycan KS and DS disseminated in the predentin impede the calcification activity of collagen fibrils; those are not calcified extracellular matrix and halt the calcification process [130,132]. There has been reported to be an intensification in KS immune-related activity around the wound area along with macrophages, reactive microglia, and oligodendrocyte precursors [128,133–135]. It has been reported that due to hereditary causes, KS can be deficient; nevertheless, little is known about the detailed reasons for deficiency [136]. One more study revealed that Morquio syndrome, or MPS, is primarily an inherited disease instigated by the insufficiency of the N-acetylglucosamine-6-sulfate sulfatase enzyme [137].

Archetypally, diminished biosynthesis KS is concomitant with inflammation, signifying proinflammatory cytokines downregulated ion of KS formation, thereby causing delayed wound healing [138].

HA is a carbohydrate-containing polysaccharide (GAG). It is considered a unique biomolecule serving multiple purposes, such as osteoarthritis, vesicoureteral reflux, urinary incontinence, skin wrinkles, dry eyes, and interstitial cystitis. HA also addresses pharmaceutical, aesthetic, and cosmetic issues through wound restoration and tissue rejuvenation [139–142].

HA GAG is a foremost and organic constituent of the extracellular matrix. However, HA contributes to diverse living cellular accomplishments by incorporating growth factors and comparative receptors. Nevertheless, the controlling physiological role of HS on the vasculogenesis of mesenchymal stem cells remains obscure [143]. Hayano *et al.* [144] first reported the "functional roles of HS proteoglycans' sulfation in dentin formation." Duplancic *et al.* [145] said that consuming manmade derivatives of heparan sulfate glycosaminoglycan (HS GAG) and blemished extracellular matrix (ECM) with therapeutic intention effectively regenerates periodontal tissue among animal models suffering from periodontal diseases. However, the pharmacodynamics of HS GAG therapeutic intervention for periodontal disease in humans is still undetermined [145].

HA is essential in maintaining the appropriate physiology of extracellular matrices in both pulpy and solid constituents of gum and tooth [146]. HA possesses anti-inflammatory, anti-edematous, osteoinductive, pro-angiogenetic properties, and antimicrobial effective pharmacodynamics, especially for periodontal diseases in managing gum infection and hemorrhage [140,141,147]. It has been reported that topical (gel formulation) HA has been documented as an accessory medication to improve long-lasting inflammatory illnesses like periodontitis, especially after dental surgical intervention through reducing inflammatory intercessors and improving healing and tissue regeneration [148–151] and oral lichen planus (topical 0.2% HA) [152–154]. HA also potentiates the periodontal wound healing process [150]. It has been reported that HA 0.8% and chlorhexidine digluconate 0.05%–0.2% avert the growth and development of dental biofilm [155–158]. High molecular weight HA and chlorhexidine thoroughly fine-tune the gums and humidify, dampen, and rinse the buccal mucus-secreting membrane [158–160]. Therefore, it revealed day-to-day oral cleanliness after periodontal therapeutic intervention, oral, or peri-implant surgery [158,161,162].

Proteins

The specific role of dietary proteins in systemic inflammation has not been elucidated [163]. It has been reported that animal and plant proteins generate insulin-like growth factors (IGFs) equally [164,165].

Furthermore, reducing the animal protein-rich diet decreases all-embracing and all forms of cardiovascular death compared to plant protein-based food [166,167]. IGFs are mitogens that promote the carcinogenesis process. These IGFs are indispensable components for developing diverse cancers and their metastatic activity. IGF biomolecules surmount normal apoptosis and promote cell cycle progression and angiogenesis process. The IGF events are arbitrated and completed by the IGF-1 receptor involved in cell transformation provoked by carcinoma [168–172].

Conversely, the ingesting of a high vegetable-proteins-based diet has been associated with a decreased risk of cardiovascular disease, type 2 diabetes mellitus, and chronic kidney disease [173–175]. In a study by Staufenbiel *et al.* [176], a comparison was made between the periodontal health of 100 vegetarians and 100 nonvegetarians. The findings revealed that the vegetarian group exhibited considerably shallower periodontal pockets, less bleeding upon probing, and better oral hygiene than the nonvegetarian participants. Therefore, the vegetarian diet appears to exert a beneficial impact on periodontal health [176].

A randomized clinical trial was conducted for 4 weeks to determine the relationship between dietary vegetables (vegetables half in quantity with a high-fat diet) and animal protein and periodontal health [177]. A vegetable-rich diet containing, e.g., seeds, nuts, cereals, marine vegetables, extra-virgin olive oil, cocoa, legumes, tomatoes, and so on, contain Mg^{2+} was more favorable toward oral health when compared with a diet rich in HC and animal protein [12,177]. Relevant studies also found that nutritional supplementation, especially protein, minimizes periodontal probing depth, reduces clinical attachment of teeth salvage, which was about to be lost, and curtails inflammatory oozing fluid caused by periodontitis. In addition, the hemorrhagic tendency was reduced on probing 2–6 months later while conduction surgical intervention was conducted for check-ups [177,178]. Multiple studies reported that individuals consuming a diet containing plenty of vegetables, fruits, soya containing various foods, and fish get more micronutrients and antioxidants [179]; after that, these folks suffer much less from periodontal diseases and dental carries than a diet rich in animal protein (Fig. 4) [12,17,38,179]. One more study revealed that a substantial portion of red meat consumption was expectantly connected with vaster periodontal probing depth and hemorrhage on probing. Correspondingly, a small amount of red and/or processed meat intake was linked to bringing down the likelihood of emerging periodontal diseases [180,181].

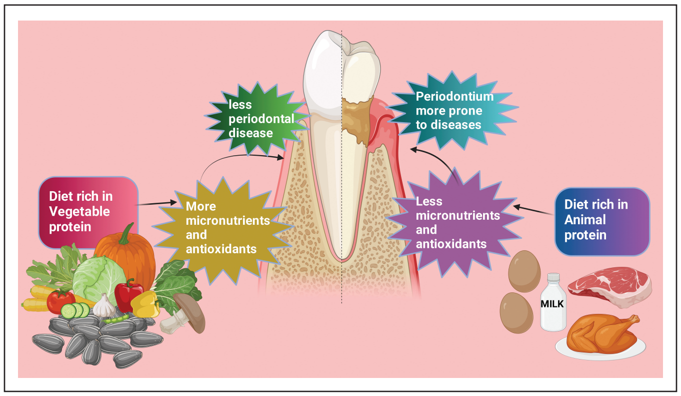

Figure 4. Illustrates the beneficial effect of a diet containing high vegetable protein on periodontal health compared to consuming high animal protein. This figure has been drawn with the premium version of BioRender (https://biorender.com/ accessed on 30th December 2023) with the license number NU269YDO3T. Image Credit: Rahnuma Ahmad.

Function of proteins over periodontal health

We receive amino acids [small carbon-based particles that contain an α (central) carbon atom linked to an amino, and a carboxyl group, atomic hydrogen, and a wavering constituent termed a side chain] from proteins, which are the building blocks of protein [182]. It has been revealed that protein is responsible for nearly all physiological commitments and rheostats gene countenance. A considerable portion of the essential constituents of every single cell of a living creature are made with protein [183,184]. Around 50% of the body's dry weight is made up of protein [185,186]; it is the second most prevalent material after water. The intracellular protein network's cytoskeleton preserves cells' physical integrity and shape [187]. The contractile components of muscle are made up of actin and myosin filaments [188].

Periodontal implication

Proteins are necessary for effective host defenses [189]. They are elements of protective molecules and barriers that aid in limiting the spread of disease [190]. The complement system, innate immunity, antibody or humoral immunity, and cell-mediated immunity are all part of the periodontal defenses [191]. The junctional and crevicular epithelia provide an epithelial barrier function against invaders for periodontium [192–194]. This epithelium surface, which has a rapid turnover, is a significant defense barrier against invading microorganisms, poisonous substances, and antigens [195]. The epithelial defense barrier needs enough protein, Zn^{2+}, folic acid, iron, vitamin A, and vitamin C to maintain good periodontal health [21,196,197].

Osteoporosis of the alveolar, supporting bone, and removing fibroblasts and connective tissue fibers in the periodontal membrane are degenerative lesions created in the periodontium [198,199]. Protein deficiency hinders periodontal wound healing by preventing angiogenesis, fibroblast growth, and collagen production, build-up, and remodeling [200–202].

The mechanisms by which protein deficiency enhances periodontal disease

The salivary antimicrobial peptides (AMPs) act as natural primary protective strategies for the oral and gastrointestinal anatomical structures from pathogenic microbes [203]. Oral saliva contains AMPs such as Mucin-7 and lactoferrin [204]. These salivary AMPs consent to beneficial microbes (microbiota) colony formation of the buccal space. However, microbiota avert wide-ranging pathogenic microbial settlement and prevent infection. Subsequently, maintain stability and composure around the mouth and oropharyngeal anatomical structure. Thus, it prevents infectious disorders in and around the mouth cavity [203,205]. Patients admitted to the intensive care unit with ventilators often produce minimal salivary secretion, enhancing poor oral hygiene [206,207]. These issues raise the possibility of developing pathogenic microbes [208,209]. Therefore, these pathogens cause oral infective diseases, including periodontitis [203–209].

Individuals consuming protein more than 1 g/kg/day is related to a diminution of periodontal infective and inflammatory disorders [35,210], and dietary Ca^{2+}, principally adequate amount drinking milk also shows defensive activities against gum disorders [211]. Periodontitis is highly prevalent in the elderly community (82%) and older adults [211–213]. It can be assumed that the elderly community regularly does not consume enough amount protein and maintain oral hygiene properly, causing periodontal diseases [35,214]

Lipids

Lipids are essential energy sources and are crucial structural and metabolic components [215–217]. Numerous studies have demonstrated that consuming unhealthy saturated fats, including trans fats and omega-6 fatty acids, significantly promotes inflammation [218–221]. Saturated fats are common in animal products, e.g., fowls with skin, fatty meats (beef and pork), pork white fat, and full-cream milk products (butter, cheese, and whole milk) [222,223]; vegetable oils (coconut and palm) [224–226]; and prepackaged or fast foods such as pastries and biscuits [227,228]. Trans fats are a type of unhealthy fat formed through industrial hydrogenation, which converts liquid oils into solid fats. Consuming trans fats has increased the risk of noncommunicable diseases (NCDs), such as heart disease and other health tribulations [221,229–232].

Multiple research projects observed a significant positive correlation between the intake of saturated fatty acids and the prevalence of periodontal lesions [17,181,233–236]. In recent years, there has been considerable research interest in omega-3 fatty acids due to their potential association with reduced systemic inflammation [237–240]. This concept is commonly known as the resoleomics theory, initially introduced in the study by Serhan and his team [17,241–247]. Serhan and associates initiated the term resoleomics in 1996 [248,249]. It is the course of decreasing inflammation. Resoleomics can be cogitated as the evolution set-up for renovating homeostatic equilibriums following infection, injury, and inflammation [248,249]. Numerous clinical studies in periodontology have shown that supplementing with omega-3 fatty acids, whether through fish oil supplements, consumption of fatty fish, or plant-based sources, can decrease periodontal inflammation and/or pocket depth [14,250–254]. Researchers chose imperative Randomized Controlled Trials Regarding Diet and Periodontal Diseases Published in the last 5 years, depicted in Table 1.

IMPACT OF MICRONUTRIENTS ON PERIODONTAL DISEASE

Healthy, nutritious food-consuming habits and regular exercise with strict avoidance of principal risk factors of NCDs such as chronic alcohol, cigarette, processed food intake, and mainly sedentary life eventually prevent or decrease the rate of NCDs [261–265]. Furthermore, overuse of proton pump inhibitors, antimicrobials, chelating agents, and nonsteroidal anti-inflammatory drugs leads to micronutrient deficiencies [266–268]. Systemic conditions such as pregnancy, breastfeeding, and physical/mental stress require increased nutrient consumption [269–272]. Vitamins are commonly classified as fat-soluble [273] and water-soluble [274]. Fat-soluble vitamins comprise vitamins A, D, E, and K [275]. Fat-soluble vitamins cannot be excreted by the kidneys through urine [275] and stored in the tissues [276]. However, most water-soluble vitamins, except vitamins B6 and B12, get easily excreted via the kidneys [277].

Vitamin A

Vitamin A preserves the integrity of epithelial cells' gene transcription and remains a de rigueur constituent all through life [278–280]. Also, it helps in the growth, differentiation, and maintenance of epithelial tissues, bone growth, and embryonic development [281–286]. A case study of a 20-year-old lady suggested that excessive vitamin A consumption leads to gingival attritions, ulcers, hemorrhage, puffiness, gum inflammation, and forfeiture of cornification. She consumed 200,000 International Units (IUs) of vitamin A every day for 6 months to decrease pimples with skin inflammation. Discontinuation of added vitamin A exhibited gingival upgrading within 7 days. A downright typical manifestation of oral tissues was detected by the end of 60 days [287]. Multiple studies reported that excessive consumption of vitamin A affects periodontal tissues and several vital structures of the human body [288–290].

Vitamin D

Vitamin D maintains normal blood Ca^{2+} levels and metabolism of skeletal issues [291–296]. It also regulates calcium absorption from the intestines [297]. A blood Ca^{2+}

Table 1. Certain critical randomized controlled trials regarding diet and periodontal diseases were published in the last 5 years [Accessed on December 9, 2023] in the PubMed database.

Author's name	**Journal details**	**Background**	**Result**	**Conclusion**
Eberhar*et al.* [177]	J Clin Periodontol. 2022;49(4):388–400	Nutrients have vital roles in periodontal health. Processed carbohydrates, free sugar, and dairy products have pro-inflammatory effects, whereas fibers and vitamins show a protective impact.	Clinical attachment level and amount of gingival fluid were increased in the semi-vegetarian high-fat diet group.	The outcome of periodontal health showed improvement with the semi-vegetarian diet, which included higher fat.
Stańdo *et al.* [253]	Nutrients. 2020;12(9):2614	Host immunity is vital in preventing periodontitis. Omega-3 polyunsaturated fatty acids (PUFA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) are found to have anti-inflammatory and immune-modulating effects.	Test groups supplemented with PUFA, DHA, and EPA showed improvement in periodontal health markers.	Supplementation of omega-3 PUFA at a high dose has beneficial effects on periodontitis.
Woelber *et al.* [255]	J Clin Periodontol. 2019;46(4):481–490	Certain nutrients, mainly processed and refined food, have an inflammatory impact on periodontal health. The outcome of an oral health-promoting diet is not firmly established.	Patients who took an oral health-promoting diet showed reduced incidence of gingival bleeding, but no significant association was found with inflammatory markers.	Gingivitis is negatively correlated with the evaluated diet.
Bartha *et al.* [256]	J Periodontal Res. 2022;57(6):1198–1209	Mediterranean diet (MedD) consists of a more balanced omega 6 and 3 ratio. Data is scarce on the effect of serum omega-PUFA on gingivitis and whether supplemental intake has any beneficial impact	The MedD group showed a significant reduction of omega-6 levels in serum, decreasing bleeding and probing.	Reduced omega-6 levels due to intake of MedD may be responsible for improvement in gingival parameters.
Bartha *et al.* [257]	J Clin Periodontol. 2022;49(2):111–122.	The Western diet (WD) mainly consists of processed food, white sugar, and low fiber content; this dietary practice promotes inflammation in the oral cavity. MedD, in contrast, has anti-inflammatory properties.	Parameters of gingival inflammation were significantly reduced in the MedD group, even in the presence of plaque.	MedD can play an essential role in reducing gingivitis.
Persson *et al.* [258]	BMC Oral Health. 2023;23(1):544	In patients with diabetes type 2, an Okinawan-based nordic diet (OBND) intake may improve periodontal health.	No significant difference was noted in the OBND group regarding periodontal parameters, although the improvement was more remarkable.	OBND diet may decrease cytokine levels.
Rakyoo*et al.* [259]	Gerodontology. 2023;40(3):382–389	Maintaining oral health is vital to prevent malnutrition in the elderly population. Early loss of teeth may jeopardize proper nutrition intake, especially protein. Application of dentures and appropriate dietary advice may improve protein intake.	Animal protein intake was higher in the test group, but no difference was seen in the case of plant protein.	Dietary advice is necessary for people who receive dentures to increase protein intake in aged persons.
Doke *et al.* [260]	BMC Oral Health. 2021;21(1):4	Metabolic syndrome (MetS) plays a considerable role in developing cardiovascular disease, and body fat causes MetS. It has been documented that cytokines released from visceral fat are associated with periodontal diseases. Increased glucose level also induces inflammation in periodontal tissues	Body water, muscle mass, and lean mass were higher in the cluster who received dental intervention, and fasting blood sugar and body weight were reduced in the same group.	The risk of Mets can be reduced by combining lifestyle modification and appropriate dental intervention.

deficiency leads to inadequate osseous tissue calcification, causing rickets and osteomalacia [298,299]. Fortified milk stands to be the primary dietary source for vitamin D. Loss of periodontal attachment has been reported with vitamin D deficiency [300]. Several studies concluded that the anti-inflammatory outcomes of vitamin D diminish the proneness of gum and periodontal diseases [301–303].

Vitamin K

Producing osteonectin and "matrix gla protein" requires vitamin K [304,305]. Intestinal microbiomes synthesize a considerable amount of vitamin K in the body [306]. Deficiency of it leads to poor bone density [307,308]. In addition, vitamin K deficiency often leads to periodontal disorders such as gum hemorrhage and tooth clinical attachment loss [31,309].

Vitamin C

The ability of vitamin C to cure scurvy gave it a name as ascorbic acid [310]. Three critical signs of inflammation, such as redness, swelling, and edema, regulated by regional blood flow, are controlled by histamine [311]. Vitamin C renders significant antihistamine properties [312] and maintains healthy periodontium [15,36,313,314]. Rebound or conditional scurvy was described in a case report by Siegel *et al.* [315], suggesting that withdrawal from chronic consumption of high doses of vitamin C leads to the development of oral symptoms of scurvy. Clinical features of scurvy are often observed within 8 to 12 weeks of sporadic or insufficient vitamin C. Canadian health authorities recommend vitamin C 75 and 90 mg daily either with food or as a supplement [316]. Another study revealed that if a patient develops obvious insufficiency symptoms because of poor consumption of vitamin C. Around 10 mg/day is recommended for many weeks [317].

Vitamin B complex

The consumption of processed food made using refined grains has increased, a significant cause of vitamin B complex deficiency with global modernization [318–320]. Energy production in the human body is mainly regulated by thiamin (vitamin B1), which is necessary to metabolize branched-chain amino acids and carbohydrates [321–323]. The classic form of thiamin-deficient disease known as Beri-Beri affects the muscular, neurological, cardiovascular, and gastrointestinal systems [322–326]. Consuming an imbalanced diet deficient in thiamin can lead to Beri-Beri within 7–10 days. Primary dietary sources for thiamin are "whole grains, cereals, nuts, seeds, meat (especially pork, with much less in fish, poultry, beef, and lamb), round beans, peas, lentils, soy and Marmite, Vegemite, Bovril," fortified bread, and orange juice [327]. Oral manifestations of thiamin insufficiency, such as glossitis, angular cheilosis, stomatitis, burning tongue, loss of taste, and hypersensitivity to the oral mucosa, are often associated with riboflavin scarcity [328].

Pellagra is a sporadic systemic disorder caused by an acute paucity of niacin (vitamin B3) in the human body [329–330]. Pellagra comprises the troika of "dermatitis, dementia, and diarrhea" and can result in fatal outcomes [324]. Pellagra was eradicated in the USA due to the fortification of the finest type of wheat flour with niacin in the preliminary days of the 1940s [331]. Niacin is synthesized from tryptophan [332] and is involved in several cellular pathways, which include the energy-building process for the coalescences and metabolism of fatty acids [333–338]. Elevated levels of cholesterol can be treated with niacin [332]. One more study reported that Vitamin B3 is associated with hepatic toxicity and failure when regularly consumed over 2 g daily [339]. "Pyridoxal, pyridoxine, and pyridoxamine;" these 03 compounds are formed from vitamin B6 [340]. Its primary function is to synthesize heme [341]. In addition, carpal tunnel syndrome can be treated with vitamin B6 [342] with varying degrees of long-term success. However, high doses stored in the body lead to irreversible nerve damage [343].

Folate or folic acid is the most integral vitamin for DNA synthesis [344]. Folic acid closely works with vitamin B12 to regenerate folate coenzyme [345,346]. The synthesis process of folate coenzyme without vitamin B12 remains "either from a failure to provide the proper substrate for polyglutamate synthesis or to a direct requirement for vitamin B12 for polyglutamate synthesis" [347]. Megaloblastic anemia with considerably greater size immature red blood cells is evident because of vitamin B12 (cobalamin) and folate insufficiencies, which are obligatory components for the generation of DNA [348]. In a study performed using data from NHANES 2001/02, where subjects underwent periodontal health checkups and serum folate level ascertainment, it was concluded that low serum folate level was independent of periodontal disease in the issues. Hence, a statistically significant negative association had been established [349]. Multiple studies reported that low-level serum folic acid promotes periodontal diseases [29,350,351]. Animal-derived foods, the primary source of vitamin B12 [352], are often deficient in strict vegetarians and vegans [353–355]. Thus, supplemental cyanocobalamin is a must for them to maintain folate and homocysteine metabolism. Pernicious anemia is the prime disorder linked with vitamin B12 deficiency [356,357]. The characteristic features of pernicious anemia include tiredness, feebleness, wishy-washy look, changes to visualization and odor, prickling feeling, overactive bladder, melancholy, unhappiness, and psychotic attacks [358]. Researchers selected an imperative Systematic Review and Meta-analysis Regarding Diet and Periodontal Diseases Published in the last 5 years depicted in Table 2.

Minerals

Minerals comprise 4% to 5% of the body weight [369,370]. Minerals maintain "heart rhythm" [371], "muscle contraction" [372], "nerve conduction" [373], and "acid-base balance" [374]. Minerals required in the amount of >100 mg/day are called significant minerals [375], and those needed in the amounts of <100 mg/day are termed trace minerals [376]. Leading minerals include "Na^+, K^+, Ca^{2+}, Mg^{2+}, P^{3-}, and S^{2-}" for maintaining human physiology [377]. In contrast, silhouette amounts of elements include "Fe^{3+}, Zn^{2+}, I^- , Se^{+4}, F^-, Cu^{2+}, Cu^{3+}, Co^{+3}, Cr^{+3}, Mn^{2+}, Mn^{3+}, and Mo^{3+}" [378,379].

Na^+ is the primary electrolyte in the body, constituting a significant part of extracellular fluid [380]. The body's fluid balance and nerve conduction are maintained by Na^+ [381]. Ha reported in 2014 that 5 to 6 g/day is the set daily requirement of Na^+ hypertensive patients [382]. K^+ is the notable cation for intracellular fluid and functions similarly to sodium but intracellularly [381]. Low K+ levels are more common as it is not often added as a dietary supplement, resulting in muscle cramps, confusion, irregular heartbeats, and life-threatening situations (Fig. 5) [381].

Research by Nishida *et al.* [383] recommended that inadequate food available calcium intake resulted in severe periodontal diseases. Shimazaki *et al.* [384] suggested an optimistic relationship between the intake of lactic acid-comprehending foods and the inhibition of the development of periodontal diseases. The electron transport functions of mitochondria are regulated by coenzyme Q10, which is dispersed from end to end of human tissues [385]. Treatment of periodontally compromised patients with this coenzyme has significantly improved in periodontal conditions [386,387]. Zinc acts on ROS and neutralizes, hence reducing the chronic inflammatory process and improving periodontal health [388–392].

Table 3 [19] was created summarizing the recommended daily doses for essential nutrients and their importance in periodontal health. References supporting the recommended doses were added to enhance the credibility

Table 2. Several analytical, systematic reviews and meta-analyses regarding diet and periodontal diseases were published in the last 5 years [Accessed December 9, 2023] in the PubMed database.

Author's name	Journal details	Background	Result	Conclusion
O'Connor *et al.* [236]	Nutr Rev. 2020;78(2):175–188.	Periodontitis, a common phenomenon of old age, can cause early loss of teeth. No strong link was found between periodontal inflammation and deficiency of nutrition	Vitamin E and C, fatty acids, beta carotene, fermented dairy products, milk, fruits, vegetables, and fiber: an adequate intake improves periodontal health.	Further large-scale studies are needed.
Ramseier *et al.* [359]	J Clin Periodontol. 2020 Jul;47 Suppl 22:90–106	Modification of health behavior is of utmost importance in controlling NCDs. Periodontal health also benefits from such modification, but data on the impact of behavior change is scarce	Discontinuations of smoking and well-managed diabetes were found to strengthen periodontal health. Data were limited to weight management, diet modification, or physical workout	Avoidance of smoking and management of diabetes have a positive impact on periodontitis
Choowong *et al.* [360]	Nutr Rev. 2022;80(5):1160–1178	Like many other chronic diseases, periodontitis is also affected by nutrition. Information on the mechanism and impact of macronutrients on periodontal health in animal models is still discrete.	A diet containing high cholesterol, refined carbohydrates, saturated fat, or inadequate protein contributes to developing periodontitis in rodents.	Data on how macronutrients affect the progression of periodontitis is limited and inconsistent.
Kusama *et al.* [361]	Nutrients. 2022;14(21):4444	Sugar-containing food is a well-known risk factor for developing dental caries, but its association with gingivitis and periodontitis is not mentioned in previous studies.	Among 13 studies, 11 papers showed a significant positive association between free sugar intake and periodontal diseases.	As most were cross-sectional studies, further longitudinal studies are needed for a firm conclusion.
Swarnamali *et al.* [362]	Nutrients. 2023;15(18):4034	The condition of periodontal tissues depends on proper diet with appropriate nutrition. Fiber in diet plays a vital role in reducing the risk of periodontal inflammation, but data primarily are derived from animal models or small studies.	Adequate fiber in the diet significantly reduced bleeding on probing and clinical attachment loss. It also reduced plaque index, gingival index, and area of inflammation in the periodontal area.	Fiber-rich diet is an effective intervention in periodontal inflammation
Samborska-Mazur *et al.* [363]	Reumatologia. 2020;58(4):236–242.	Both periodontitis and rheumatoid arthritis are chronic inflammatory disorders that have similarities in risk factors and disease progression	The role of smoking and bacteria were well established, along with increased levels of proinflammatory cytokines in both disorders	Elaborative studies are needed as present research papers show numerous disparities.
Jeong *et al.* [364]	Nutrients. 2022;14(20):4362	Periodontitis is prevalent among older people worldwide. Several nutrients have been reported to be associated with this chronic inflammatory condition of the oral cavity.	Low intake of ascorbic acid and a diet rich in dairy products, sugar along with a WD, increased the risk of periodontitis	Avoidance of certain nutrients may lower the risk of periodontitis.
Halvorsrud *et al.* [365]	J Dent Res. 2019;98(1):46–53	World Health Organization advocates for a carbohydrate-rich diet low in free sugar. The effects of starch on oral health are still unclear in the literature.	Slowly digestible starch (SDS) has some protective effects on periodontitis, but the quality of data was not satisfactory	SDS intake should be encouraged to prevent periodontal inflammation.
Mainas *et al.* [366]	Clin Oral Investig. 2023;27(8):4107–4116	Animal studies have shown that calorie restriction (CR) to a certain amount promotes health, but clinical research on periodontal health is few with discrepant results.	Patients with periodontitis may benefit from CR to some extent.	As data were heterogeneous and insufficient, robust studies are required to draw a firm conclusion.
Smits *et al.* [367]	Community Dent Oral Epidemiol. 2020;48(1):7–13	The role of a balanced diet in periodontal health is well documented in the literature, but data is scarce on the link between a vegetarian diet and periodontitis.	Qualities of the data were not satisfactory. However, available scientific literature shows that a vegetarian diet increases the risk of dental erosion.	With available data, no firm conclusion could be reached.
Woelber *et al.* [368]	Nutrients. 2023;15(6):1538.	Among the preventable risk factors of periodontitis, the impact of dietary interventions is not well established yet.	Periodontal parameters were improved significantly with the intake of tocopherol, oolong, green tea, juice powder, and chicory extract.	Dietary interventions can play a vital role along with surgical interventions in periodontitis

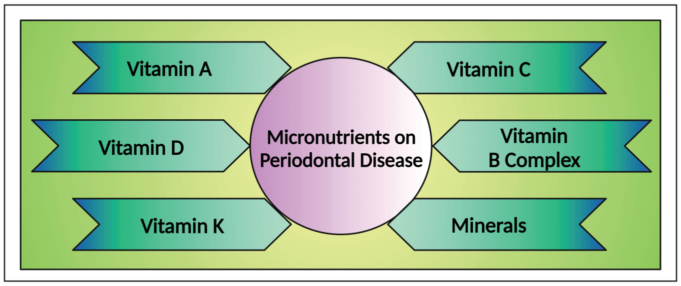

Figure 5. Illustrates the impact of micronutrients on periodontal disease. This figure has been drawn with the premium version of BioRender (https://biorender.com/ accessed on 21st December 2023) with the license number IS268O3U4S. Image credit: Susmita Sinha.

Table 3. Recommended daily doses to maintain periodontal health.

Nutrient	Recommended daily doses	Importance in periodontal health
Vitamin A	Male: "900 mcg or 3,000 IU." Female: "700 mcg or 2,333 IU"	Deficiency leads to decreased immune cell differentiation, antigen response, antibody production, immunoglobulin production, lymphocyte production, and increased bacterial adhesion
Vitamin B	"Vitamin B1 (Thiamin): 1.2 mg; B2 (Riboflavin): 1.3 mg; B3 (Niacin): 16 mg; B5 (Pantothenic Acid): 5 mg; B6 (Pyridoxine): 1.7 mg; B7 (Biotin): 30 mcg; B9 (Folate/Folic Acid): 400 mcg; B12 (Cobalamin): 2.4 mcg."	Accelerated post-surgical healing
Vitamin C	Adult Male: 90 mg Adult Female: 75 mg	Controls gingival bleeding and promotes collagen formation.
Vitamin D	Adults (under 70 years): 600 IU Adults (70 and older): 800 IU	Local application accelerates post-surgical healing and osseointegration
Vitamin E	"15 mg or 22.4 IU".	No significant effects on periodontal therapy
Vitamin K	Male: 120 mcg Female: 90 mcg	Deficiency affects gingival bleeding

This table was developed based on Kozeniecki *et al.* [19].

of the information. The reliability and validity of selected studies were critically appraised to ensure the robustness of the evidence. Potential biases, limitations, and gaps in the existing literature were acknowledged and discussed.

LIMITATIONS OF THIS REVIEW

The limitation of this review was the complete reliance on the previously published manuscript. Only PubMed, Medline, and Scopus databases were consulted. We may have missed the research work published in Web of Science and other smaller databases. In addition, multiple studies reported that narrative review possesses integral limitations such as substandard research paper exploration [393], scarcity of explicit substantiation of search strategy [394], imaginable preferential in the evaluation of selected scientific articles [395,396], according to SANRA scale score below four denotes poor quality of the paper [397], and not appropriate specific clinical situation [398]. These traditional reviews help as potential resources for the speedy accessibility of recent references for precise arenas of interest of authors [399–401]. However, it has been reported that narrative reviews postulate better explanation and appraisal; the strategic impact of these old-style review papers extends comprehension level [402–404].

CONCLUSION

As is observed throughout this review, nutrition plays a vital role in oral cavity health. Each nutrient has its own function, and nutrients also interact to boost and sustain a healthy periodontium. Nutrients such as carbohydrates in the form of GAG are essential for extracellular matrix formation, proteins contribute to host immunity, and lipids like omega-3 fatty acids may decrease the chronic inflammatory process. Vitamin C is needed to avoid gum bleeding, and vitamin K deficiency leads to periodontal disorders such as gum hemorrhage and tooth clinical attachment. Mineral deficiency, like calcium deficiency, causes periodontal disease and zinc neutralizes ROS. Poor oral health may hamper physical, mental, and social well-being. To maintain oral health, it is, therefore, vital to know about the benefits of these nutrients. It is essential to spread this knowledge among the general population. Dentists, other health workers, and policymakers need to work together to ensure the dissemination of knowledge regarding proper balanced diet consumption in adequate amounts, sources of various nutrients, and harmful effects of an unhealthy diet, as well as a diet deficient in essential nutrients on oral health. Research in this field of study must continue to build awareness and prevent damage to oral health so that the global population can enjoy a healthy smile.

ACKNOWLEDGMENT

The graphical abstract has been drawn with the premium version of BioRender (https://biorender.com/ accessed on 29th December 2023) with the license number MF269TMZ3R. Image Credit: Rahnuma Ahmad.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

FINANCIAL SUPPORT

This research received no external funding.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVALS

This is narative review. Ethical approval not required.

DATA AVAILABILITY

Not applicable.

PUBLISHER'S NOTE

This journal remains neutral with regard to jurisdictional claims in published institutional affiliation.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

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How to cite this article:
Dattani V, Patel H, Ahmad R, Sinha S, Girdhar G, Shetty A, Haque M, Kumar S, Chowdhury K. Aspects of nutriment in maintaining gum wellbeing: A literature review. J Appl Pharm Sci. 2024.
http://doi.org/10.7324/JAPS.2024.1704606786