Scripta Scientifica Medicinae Dentalis, 2024;10(1):14-21
DOI: 10.14748/ssmd.v10i1.9172

ISSN 2367-7236 (Print)
ISSN 2367-7244 (Online)

REVIEWS

INFLUENCE OF WATER- AND FAT-SOLUBLE VITAMINS ON ORAL HEALTH IN ADOLESCENCE

Kristiyana Mineva, Milena Georgieva-Dimitrova

Department of Pediatric Dentistry, Faculty of Dental Medicine, Medical University of Varna, Bulgaria

ABSTRACT

Adolescence is a period of transition between childhood and adulthood. A number of functional, physical, psychological, sexual, and emotional changes occur. This important period introduces the adolescent to the world of adults. Cognitive and social changes often bring worry and anxiety not only to the adolescents, but also to their family. Due to the onset of puberty, skeletal mass, body fat, and lean body mass increase. This leads to the need to increase caloric food intake. Vitamins are necessary for the processing of macronutrients (proteins, carbohydrates, lipids) and micronutrients (minerals). They take part in the formation of blood cells, hormones, and genetic material, in the transmission of nerve impulses, and in maintaining the immune system. Vitamins act as coenzymes to help enzymes perform their functions in the body.

Keywords: *adolescence, vitamins, oral health, nutrition*

INTRODUCTION

Nutrition is essential for the growth and development of children and adolescents. It contributes to their health and well-being, helps in the fight against obesity and a number of chronic diseases. A balanced diet is one that has covered all the macro- and micronutrient needs. It has been found that, even in the most developed countries, a large part of the population does not get essential vitamins and minerals in their diet, and even groups of the population are at risk of nutritional or emotional disorder, and physiological stress. The risk is greatest for pregnant women, nursing mothers, children, adolescents, smokers, alcoholics, the elderly, and the chronically ill (1).

Macro- and micronutrients, to which vitamins belong, have a vital importance in the balance between the risk factors for the development of systemic and dental disease and the response of the macroorganism. The appearance and progression of the disease depends on this balance (2).

Unhealthy diet during childhood and adolescence is associated with health consequences. Inadequate dietary intake of energy, proteins, and certain trace elements leads to changes in growth rates, delay in sexual maturation, inadequate bone mass, and insufficient amount of vitamins and minerals in the body. In the future, the risk of developing health problems increases, such as obesity, iron deficiency, dental caries, and gingival inflammation. A reduced resistance of children to infectious diseases is observed. Nutrition is important for adolescents as it affects their mental and physical development (3).

Physiological changes during puberty, as well as brain maturation, inevitably lead to changes in eating behavior. A key process that distinguishes adolescence is bone development. This imposes additional nutritional requirements during puberty. The right choice of a healthy diet based on a good food pattern is important. Parents have an essential role in this choice. Modern food pyramids show a shift from animal-based foods to plant-based foods. In turn, foods of animal origin have been replaced by

Address for correspondence:
Kristiyana Mineva
Faculty of Dental Medicine
Medical University of Varna
84 Tzar Osvoboditel Blvd
9000 Varna
Bulgaria
e-mail: kristiyana.mineva94@gmail.com

Received: February 13, 2024
Accepted: April 26, 2024

© The Author(s) 2024. This is an open access article distributed under the Creative Commons Attribution License (CC BY), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

the consumption of legumes, whole grains, vegetables, fruits, and nuts. This type of eating pattern improves health while protecting the environment (4).

Due to the physiological changes during puberty, the need to increase the total nutritional intake and energy requirements also increases. Most often, adolescents have diets poor in vitamins and minerals, including folic acid, vitamins A, C, B6, and E, iron, magnesium, zinc, phosphorus, and calcium (5). Additionally, fewer adolescents are consuming dietary fiber as opposed to saturated fat, sodium, cholesterol, and added sugar. Radhi et al. examined vitamins A, C, E, and total protein, which are part of the composition of saliva (6). The results showed that the value of these vitamins and total salivary protein was significantly lower in malnourished children (7).

Adolescent males have a significant increase in weight and lean body mass as well as height, therefore they have a greater need for calories than adolescent females. In addition, adolescents who are more physically active and have greater muscle body mass need additional energy to meet their needs (5).

Vitamins are organic substances that are needed in small amounts for proper growth, development and optimal health. They are divided into 2 large groups—fat-soluble and water-soluble vitamins. Fat-soluble vitamins include: vit. A, vit. D, vit. E, vit. K. The group of water-soluble vitamins includes: vit. C, vit. B1, vit. B2, vit. B6, vit. B12, folic acid, biotin, and pantothenic acid (8).

The dynamics of dental development are directly related to complete nutrition. In the formation of tooth germ and the initial mineralization phases, the nutritional status and vitamin deficiency have a significant impact. There is a direct link between malnutrition, vitamin deficiency, and disturbances of primary teeth, such as hypoplasias and hypomineralizations (2). In general, malnutrition and associated vitamin deficiency increase the occurrence of enamel hypoplasia in children (9).

Vitamin deficiency is expressed not only by insufficient growth and development, but also by manifestations on the oral mucosa (tongue, lips, soft tissues). Hypovitaminoses are accompanied by several non-specific oral conditions, such as glossitis, stomatitis, and aphthae. Linear glossitis is thought to be an early sign of vitamin B12 deficiency (10).

FAT-SOLUBLE VITAMINS

Fat-soluble vitamins—vit. A, vit. D, vit. E, and vit. K, are absorbed through the intestinal walls with the help of fats in the food or the bile produced by the liver. They are not destroyed by cooking. They are stored in body fat. Vitamin A and D accumulate in the body with hypervitaminosis occasionally being observed (11).

Vitamin A

It is also known as retinol and is the active form of the vitamin. It helps to build and maintain healthy tissues, such as skin, hair, nails, and mucous membranes. Vitamin A supports good vision and the immune system. When obtained from food sources, it is known as preformed vitamin A. It is found in animal foods such as liver, fish, fish liver oil, eggs, and fortified whole milk. Beta carotene is the precursor of vit. A and it is contained in yellow-green fruits and vegetables, such as broccoli, spinach, carrots, sweet potatoes, apricots, pumpkins, and melons (8).

Good sources of vitamin A can be: beef liver, chicken breast, milk, yogurt, ricotta cheese, baked beans, apricots, mangoes, tomato juice, and melons.

Vitamin A is involved in the formation of rhodopsin, necessary for the normal maintenance of the retina, in the control of epithelial differentiation and in the secretion of salivary glands, nose, throat, in bone remodeling, and in reproduction. It is essential for the membrane structures of cells and supports the health of oral structures such as teeth, periodontium, and mucosa. (12)

Vitamin A has antioxidant properties through which it supports the periodontal complex. Vitamin therapy with vitamins A, E, and K is used to treat periodontal diseases (13,14).

Recommended daily dose:

- Adolescents (10–13 years): 600 μg retinol activity equivalents (RAE)
- Boys (14–19 years): 900 μg RAE
- Girls (14–19 years): 700 μg RAE (15)

Vitamin A hypovitaminosis is associated with dry and atrophic oral mucosa, often accompanied by angular cheilitis. The lips are dry, cracked, with the presence of crusts on them. Angular cheilitis can also be observed in vit. A hypervitaminosis (16).

Vitamin D

Vitamin D exists in three forms and only two of them, vitamin D2 and D3, are of nutritional importance. The D2 form is called ergocalciferol, the D3 form is called cholecalciferol, and both are fats. They are stable to culinary processing, storage and acidity, but are sensitive to light irradiation. Vitamin D2 is derived from the provitamin ergosterol present in plants, fungi, and yeast. D3 is the synthetic form of the vitamin, when ergosterol is irradiated with ultraviolet light. Cholecalciferol is the naturally occurring form of vitamin D in animal tissues and is produced in the skin. Its precursor, 7-dehydrocholesterol, is converted to D3 when irradiated by light. Vitamin D belongs to the fat-soluble secosteroids. This class of steroids helps the absorption of calcium, magnesium and phosphate (11).

Optimal amount of vit. D can be achieved by biosynthesis in human skin (17). In the absence or insufficient UVB irradiation of the skin, vit. D must be obtained through food or additional supplementation (18, 19). Bulgaria is included in the list of European countries with insufficient intensity of UVB light in winter (20). This is so because of its location from 41°14' to 44°12 N latitude (21).

Vitamin D3 occurs naturally but in small amounts in egg yolk, liver, fish, such as herring, sardines, tuna, and salmon. Vitamins D2 and D3 are equally powerful as nutritional supplements. Milk and cheese are products with an excellent supply of calcium and phosphorus. Vitamin D supports their absorption for the proper development of teeth and bones. For this reason, milk and dairy products are the only foods fortified with vitamin D. Breast milk is not a complete source of vitamin D. Vitamin D supplements are prescribed by pediatricians for pregnant women, nursing mothers, and adolescents (12).

Vitamin D is vital for a number of organs and systems, and their proper functioning (immune system, brain function) (22).

Vitamin D functions as a vitamin and as a hormone, because it is present in food, but it is also formed in the skin. It affects distant target organs and, in particular, the gastrointestinal tract and bones. The main action of the vitamin is to promote the absorption of intestinal calcium and phosphate. Both calcium and phosphorus are involved in the formation and functioning of bones, teeth, nerves, and muscles. By maintaining adequate levels of serum calcium and phosphorus, vit. D also affects the parathyroid glands.

Recommended daily dose:

- Adolescents (10–19 years): 15 μg (600 IU) (23)

A higher body mass index (BMI) was found to be a predictor of lower vit. D intake in adolescents (18).

Vitamin D deficiency is associated with the two most common oral diseases—caries and periodontal diseases. Decreased bone density and progression of periodontal diseases are observed. It is also a risk factor for the development of early childhood caries (24, 25).

Vitamin D deficiency leads to inferior lamina dura of both temporary and permanent teeth. There is a low mineralization of the dentin, delayed tooth eruption, delayed development and closure of the apex of the root canals, development of periapical abscesses of non-cariogenic origin, and trauma of the teeth. A deficiency of this vitamin means that it is possible that the pulp horns are with higher exposure, the pulp chamber is enlarged, and taurodontism is observed (26,27).

Vitamin E

Vitamin E is also known as tocopherol. This is a group of vitamins whose main function is as antioxidants. Tocopherols serve to eliminate free radicals obtained during oxidation-reduction processes in the body (23). In addition, vitamin E aids in the formation of red blood cells, muscles, and other tissues. Vitamin E is found in vegetable oils (soybean, corn, cottonseed, safflower) and in products such as margarine made from these oils. Foods rich in polyunsaturated fatty acids are also rich in vitamin E (8). The requirement for vitamin E intake is proportional to the amount and degree of unsaturation of polyunsaturated fatty acids in the diet. The less polyunsaturated fats are consumed, the less vitamin E is needed (12).

Recommended daily dose:

- Adolescents (10–13 years): 11 mg
- Adolescents (14–19 years): 15 mg

Vitamin K

Vitamin K occurs in nature in two forms—K1 and K2, with the K1 group found in green plants and

cow's milk, and the K2 group being produced by bacterial synthesis in the gut. Vitamins K1 and K2 are yellowish oils, unstable to ultraviolet light and unstable to strong acids and bases. The primary function of vitamin K is to catalyze the synthesis of the coagulation factor prothrombin by the liver. Vitamin K is also essential for the production of other clotting factors, such as VII, IX, and X. In the absence of these factors, prothrombin deficiency develops and blood clotting is prolonged. Prothrombin is formed by carboxylation of a precursor protein as a result of the presence of vitamin K. In the presence of thromboplastin and calcium ions, prothrombin is converted to the enzyme thrombin. It then catalyzes the conversion of soluble fibrinogen into the insoluble fibrin that forms the blood clot.

Recommended daily dose:

- Adolescents (10–13 years): 60 μg
- Adolescents (14–18 years): 75 μg (15)

WATER-SOLUBLE VITAMINS

Unlike fat-soluble vitamins, water-soluble vitamins are not stored in the human body. This group of vitamins dissolves quickly in water and is usually easily excreted from the body. Their daily consumption through food is essential. Water-soluble vitamins are very fragile and are naturally present in food. However, a large part of them can be destroyed during preparation (11).

Vitamin C

It belongs to the group of water-soluble vitamins and is one of the heat-sensitive vitamins. Also known as ascorbic acid, it is also a powerful antioxidant. Vitamin C supports the formation of collagen and is important in wound healing (23). Vitamin C supports immunity and promotes the absorption of non-heme iron in the mucosa. It participates in the synthesis of carnitine, catecholamines, adrenaline, and noradrenaline (1).

It also contributes to the integrity of cells, such as fibroblasts, osteoblasts, and odontoblasts, involved in the development of connective tissue, bones, and teeth. The role of vitamin C in the synthesis of hormones by the adrenal gland explains its high concentration in adrenal tissues. Vitamin C is also involved in the metabolism of the amino acid tyrosine (28).

Vitamin C has a powerful antioxidant protection. A relationship between serum and salivary concentration of the vitamin has been found to decrease with an increase in caries activity in the oral cavity (29).

Sources of vitamin C are citrus fruits, tomatoes, cabbage, cauliflower, cantaloupe, strawberries, and dark green vegetables, such as broccoli, green peppers, spinach, and Brussels sprouts (8). Sprouted pulses contain very good amounts of vitamin C. Amla, gooseberry, and guava are the richest sources of ascorbic acid (23). Breast milk contains three to four times more vitamin C than cow's milk, except in cases where this vitamin is deficient. The chemical form of vitamin C is exactly the same as that contained in oranges or rose hips. The body cannot distinguish between natural and chemical sources of vitamin C (28).

Recommended daily dose:

- Children (9–13 years): 39 mg per day
- Girls (14–18 years): 56 mg per day
- Girls over 19 years: 60 mg per day
- Boys (14–18 years): 63 mg per day

Severe deficiency of this water-soluble vitamin can lead to scurvy and should therefore be prevented. Changes in periodontal tissues are observed (30).

Vitamin B1 (Thiamine)

Vitamin B1, called thiamine, is part of the group of water-soluble vitamins. Its main function is to support the metabolism of carbohydrates. It is necessary for the normal functioning of muscles and participates in the oxidative carboxylation of glucose. It is necessary for the existence of all life forms (1).

Its food sources are whole grains, wheat, yeast, legumes, oilseeds, and nuts. Meat, fish, eggs, vegetables, and fruits contain less of the vitamin.

Recommended daily dose:

- Boys (14–18 years): 1.1–1.2 mg per day
- Girls (14–18 years): 0.9 mg per day (31)

With thiamine deficiency, hypersensitivity of the oral mucosa is observed with the appearance of pain in the tongue, teeth, jaws, and face (32).

Vitamin B2 (Riboflavin)

Riboflavin is a cofactor of enzymes involved in metabolism. Its key role is involvement in cellular oxidation (33). It plays a role in the release of ener-

gy from carbohydrate metabolism and is essential for the functioning of vitamin B6 and niacin. Vitamin B2 is involved in the maintenance of mucous membranes in the human body (8). This vitamin is one of the most stable vitamins in acidic pH and with minimal losses in neutral pH (34).

Sources of vitamin B2 are milk, eggs, liver, kidney, and green leafy vegetables. Meat and fish contain smaller amounts of this vitamin (33).

Vitamin B2 deficiency is associated with dry oral mucosa, cracking and fissuring of the lips, and glossitis (32).

Recommended daily dose:

- Boys (14–18 years): 0.9–1.3 mg per day
- Girls (14–18 years): 0.9–1.0 mg per day (31)

Vitamin B3 (Niacin)

Vitamin B3, also known as niacin, nicotinic acid, and niacinamide, acts as a coenzyme facilitating energy production and is involved in tissue cell respiration (8). Niacin plays a role in metabolizing macronutrients. It is important for the normal functioning of the skin, intestines, and nervous system. Sources of vitamin B3 are liver, kidneys, meat, poultry, fish, legumes, and groundnuts. The human body can convert the amino acid tryptophan into niacin (33).

Recommended daily dose:

- Boys (14–18 years): 12–20 mg per day
- Girls (14–18 years): 12–15 mg per day (31)

Oral manifestations in vitamin B3 deficiency are presented by redness and soreness of the oral mucosa and increased salivation. Glossitis with desquamation of the epithelium and subsequently with depapillation are observed (32).

Vitamin B5 (Pantothenic Acid)

Pantothenic acid is involved in the metabolism of macronutrients—carbohydrates, fats, and proteins. It participates in the formation of hormones and substances for the regulation of the nervous system. Vitamin B5 is widely distributed in food, abundantly found in meat, whole grains, and legumes. Pantothenic acid is lost during heavy food processing and refining (8).

Recommended daily dose:

- Children (9–13 years): 4 mg per day
- Adolescents (14–18 years): 5 mg per day (30)

Children and adolescents over the age of 9 do not take pantothenic acid in the prescribed doses for their age. The lowest consumption of this vitamin was observed in boys aged 9–13 years and girls aged over 14 years (34).

Vitamin B6 (Pyridoxine)

Pyridoxine exists in three forms: pyridoxine, pyridoxal, and pyridoxamine. Vitamin B6 is an enzyme cofactor that participates in over 140 biochemical reactions, both for the synthesis and breakdown of the macronutrients (35).

It participates in the synthesis of nucleic acids and protective antibodies. It is necessary for the normal development of blood cells in the bone marrow. Sources of pyridoxine are milk, liver, meat, egg yolk, fish, whole grains and cereals, legumes, and vegetables (33). Other good sources are rice, soybeans, oats, peanuts, and walnuts. Research by Lebiedzińska A. et al. confirmed that cereals are an important source of all three B6 vitamins (35). Dairy products and red meat are relatively poor in vitamin B6.

Recommended daily dose:

- Children (9–13 years): 0.8 mg per day
- Adolescents (14–18 years): 1.1 mg per day (30)

Vitamin B7 (Biotin)

Biotin is a water-soluble vitamin that is involved in the synthesis of fatty acids. It plays a role in carbohydrate metabolism and energy release. It is also essential for many enzyme functions. Sources include liver, eggs, egg yolk, soy, flour, and grains. Fruit and meat are poor sources of vitamin B7. Biotin can also be synthesized by microorganisms in the intestinal tract (8).

Recommended daily dose:

- Adolescents (14–18 years): 20–25 mg per day (31)

Vitamin B9 (Folic Acid)

Vitamin B9 is also known as folic acid. Folic acid has a role in the synthesis of nucleic acids and participates in the formation of hemoglobin in red blood cells. Hemoglobin is the iron-containing part of erythrocytes. Sources of vitamin B9 include liver, meat, dairy products, eggs, milk, fruit, and grains (33).

The role of folic acid in tissue building is essential and is necessary for the integrity of the periodon-

tium. This is evidenced by numerous studies. There is evidence that there is reduced risk of developing clefts of the lips and hard palate when taking vitamin B9 (36, 37).

Recommended daily dose:

- Adolescents: 400 μg per day

Adolescents who take folic acid above the average need are only 1.5%, which raises concern. The intake of vitamin B9 among children and adolescents over 9 years of age has decreased (38, 39).

Vitamin B9 deficiency is associated with the occurrence of angular cheilitis, recurrent aphthous stomatitis, painful, reddened tongue, and depapilled tongue (40).

Vitamin B12 (Cobalamin)

Vitamin B12 is known as cobalamin. It participates in the formation of red blood cells, as well as in the construction of genetic material. Cobalamin helps in the functioning of the nervous system and plays an important biochemical role in the synthesis of fatty acids in the myelin (33).

Numerous studies on the causes of the development of cleft lips, palate, alveolar ridge, as well as defects in the neural tube, are associated with a deficiency or lack of B complex vitamins and more specifically vit. B12 (41,42).

Sources of vitamin B12 are liver, kidneys, meat, fish, eggs, milk, and cheese, as it is not contained in foods of plant origin. Cobalamin is also synthesized by bacteria in the colon (33). Vitamin B12 is believed to be stable during heat treatment, yet a loss of 30% of the vitamin in dairy products is reported during boiling and 7% during pasteurization (43).

Recommended daily dose:

- Adolescents (10–12 years): 1.9 μg per day
- Adolescents (13–15 years): 2.3 μg per day
- Adolescents (16–19 years): 2.4 μg per day
- Pregnancy and breastfeeding: 1.5 μg per day (33)

Hypovitaminosis B12 is associated with the appearance of Moeller-Hunter glossitis. This is atrophic glossitis, which is an early symptom of pernicious anemia. Manifestations such as angular cheilitis, exfoliative cheilitis, gum hemorrhages, and reddened areas along the oral mucosa are not excluded. Pontes et al. have also found manifestations of glossitis, oral candidiasis, angular cheilitis, and diffuse erythematous glossitis in children with cobalamin deficiency (44).

Vitamin B12 deficiency is also associated with an increase in tooth decay risk and risk of periodontal disease in childhood (45,46).

DISCUSSION

From a medical point of view, the role of vitamins is well known, while the scientific evidence regarding the perspective on oral health is not fully specified. There is a relationship between diet, development and mineralization of teeth, and the occurrence of a carious process. In the literature, information on this direct relationship is scarce and subject to discussion. It is common knowledge that vitamins have a significant impact on oral and general health, and their imbalance leads to malnutrition.

Vitamins can be a modifying factor in the progression and treatment of a number of oral diseases, as well as part of their primary prevention.

CONCLUSION

Adolescence is a key and critical moment in adolescent development. The need for proper and sufficient consumption of water-soluble and fat-soluble vitamins in a teenager's diet is of utmost importance. Vitamins ensure the proper development of all systems in the human body, especially the immune system. There is a direct link between a good immune system and the absence of dental and soft tissue problems.

REFERENCES

1. Huskisson E, Maggini S, Ruf M. The role of vitamins and minerals in energy metabolism and well-being. J Int Med Res. 2007;35(3):277-89. doi: 10.1177/147323000703500301.
2. Taqa AA, Al-Mashhadane FA. Vitamins and their relations to oral health: A review study. Int J Res. 2019;22(1). doi: 10022122019513.
3. Al-Jawaldeh A, Taktouk M, Nasreddine L. Food consumption patterns and nutrient intakes of children and adolescents in the Eastern Mediterranean region: A call for policy action. Nutrients. 2020;12(11):3345. doi: 10.3390/nu12113345.
4. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the

Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet. 2019;393(10170):447–92. doi: 10.1016/S0140-6736(18)31788-4.

5. ALjaraedah TY, Takruri HR, Tayyem RF. Dietary practices and nutrient intake among adolescents: A general review. Obes Med. 2019;16:100145. doi: 10.1016/j.obmed.2019.100145.

6. Radhi NJ. Salivary vitamins and total proteins, in relation to caries experience and gingival health, according to nutritional status of a group of five-year-old children. J Baghdad College Dentistry. 2012;24(3):129–36.

7. Sadida ZJ, Indriyanti R, Setiawan AS. Does growth stunting correlate with oral health in children?: A systematic review. Eur J Dent. 2022;16(01):32–40. doi: 10.1055/s-0041-1731887.

8. Ehrlich A. Vitamins. In: Ehrlich A. Nutrition and dental health. 2nd ed.; 1994. pp. 71-86.

9. MacKeown JM, Cleaton-Jones PE, Fatti P. Caries and micronutrient intake among urban South African children: A cohort study. Community Dent Oral Epidemiol. 2003;31(3):213–20. doi: 10.1034/j.1600-0528.2003.00042.x.

10. Cagetti MG, Wolf TG, Tennert C, Camoni N, Lingström P, Campus G. The role of vitamins in oral health. A systematic review and meta-analysis. Int J Environ Res Public Health. 2020;17(3):938. doi: 10.3390/ijerph17030938.

11. Rafeeq H, Ahmad S, Tareen MBK, Shahzad KA, Bashir A, Jabeen R, et al. Biochemistry of fat soluble vitamins, sources, biochemical functions and toxicity. Haya Saudi J Life Sci. 2020. doi: 10.36348/sjls. 2020. v05i09.007

12. Papas N. The fat-soluble Vitamins: A, D, E and K. In: Papas N. Nutrition in clinical dentistry. 3rd ed. Saunders; 1989. pp. 125-42.

13. Sobaniec H, Sobaniec W, Sendrowski K, Sobaniec S, Pietruska M. Antioxidant activity of blood serum and saliva in patients with periodontal disease treated due to epilepsy. Adv Med Sci. 2007;52 Suppl 1:204-6.

14. Khmelevskiĭ IV, Danilevskiĭ NF, Borisenko AV, Poberezkina NV. Effect of vitamins A, E and K on the indices of the glutathione antiperoxide system in gingival tissues in periodontosis. Vopr Pitan.1985;4:54-6.

15. Youness RA, Dawoud A, ElTahtawy O, Farag MA. Fat-soluble vitamins: updated review of their role and orchestration in human nutrition throughout life cycle with sex differences. Nutr Metab (Lond). 2022;19(1):60.

16. Krasteva A, Kiselova A, Panov V, Guirova B, Krasteva A, Bobeva A. Oral lesions. Sofia: I. Sapunjiev; 2011. pp.197-201. (in Bulgarian).

17. Kimlin MG. Geographic location and vitamin D synthesis. Mol Aspects Med. 2008;29(6):453–61. doi: 10.1016/j.mam.2008.08.005.

18. Hribar M, Hristov H, Lavriša Ž, Koroušić Seljak B, Gregorič M, Blaznik U, et al. Vitamin D intake in Slovenian adolescents, adults, and the elderly population. Nutrients. 2021;13(10):3528. doi: 10.3390/nu13103528.

19. Holick MF. Vitamin D deficiency. N Engl J Med. 2007;357(3):266-81. doi: 10.1056/NEJMra070553.

20. Hribar M, Hristov H, Gregorič M, Blaznik U, Zaletel K, Oblak A, et al. Nutrihealth Study: Seasonal variation in vitamin D status among the Slovenian adult and elderly Population. Nutrients. 2020;12(6):1838. doi: 10.3390/nu12061838.

21. O'Neill CM, Kazantzidis A, Ryan MJ, Barber N, Sempos CT, Durazo-Arvizu RA, et al. Seasonal changes in vitamin D-effective UVB availability in Europe and associations with population serum 25-hydroxyvitamin D. Nutrients. 2016;8(9):533. doi: 10.3390/nu8090533.

22. Lin S./The Dental Diet-The surprising Link between Your Teeth, Real Food, and Life-Changing Natural Health/Hay House INC/2018/p. 167-169

23. Verma M., John J/Textbook of Preventive and Community Dentistry-Public Health Dentistry/3rd ed./CBS Publishers & Distributors Pvt Ltd/2017/p.169-182

24. Seminario A.L., Jumani K., Velan E., Scott J.M., Latimer J., Schroth R.J./Suboptimal Serum Vitamin D Associated with Early Childhood Caries in Special Health Care Needs Children/J. Dent. Child. 2018;85:93–101

25. Kim IJ, Lee HS, Ju HJ, Na JY, Oh HW. A cross-sectional study on the association between vitamin D levels and caries in the permanent dentition of Korean children. BMC Oral Health. 2018;18(1):43. doi: 10.1186/s12903-018-0505-7.

26. Seow WK. X-linked hypophosphataemic vitamin D-resistant rickets. Aust Dent J. 1984;29(6):371–7. doi: 10.1111/j.1834-7819.1984.tb05304.x.

27. Goodman JR, Gelbier MJ, Bennett JH, Winter GB. Dental problems associated with hypophosphataemic vitamin D resistant rickets. Int J Paediatr Dent. 1998;8(1):19–28. doi: 10.1046/j.1365-263X.1998.00059.x

28. Papas N. Vitamin C (ascorbic acid). In: Papas N. Nutrition in clinical dentistry. 3rd ed. Saunders; 1989. pp.113-24.

29. Hedge MN, Kumari S, Hegde ND, Shilpa SS. Relation between salivary and serum vitamin C levels and dental caries experience in adults-a biochemical study. Nitte Univ J Health Sci. 2013;3(4):30-3.

30. Mitsopoulou AV, Magriplis E, Dimakopoulos I, Karageorgou D, Bakogianni I, Micha R, et al. Micronutrient intakes and their food sources among Greek children and adolescents. Public Health Nutr. 2020;23(13):2314–26. doi: 10.1017/S136898001900449X.

31. Carrasco-Luna J, Gombert M, Carrasco-García Á, Codoñer-Franch P. Adolescent feeding: Nutritional risk factors. J Child Sci. 2018;08(01):e99–105. doi:10.1055/s-0038-1669436.

32. Preedy V, editor. B vitamins and folate. Chemistry, analysis, function and effects. RSC Publishing; 2013. pp.93-134.

33. John J. Textbook of preventive and community dentistry. Public health dentistry. 3rd ed. CBS Publishers & Distributors Pvt Ltd.; 2017. pp.175-81.

34. Lambert J, Agostoni C, Elmadfa I, Hulshof K, Krause E, Livingstone B, et al. Dietary intake and nutritional status of children and adolescents in Europe. Br J Nutrition. 2004;92 Suppl 2:S147-211. doi: 10.1079/bjn20041160.

35. Lebiedzińska A, Marszałł M, Grembecka M, Czaja J, Szefer P, Kuta J, et al. Detection of B6 vitamers in grain products: experimental and computational studies. Food Anal Methods. 2018;11:725–32. doi 10.1007/s12161-017-1045-5.

36. Doğan A, Tunca Y, Ozdemir A, Sengül A, Imirzalioğlu N. The effects of folic acid application on IL-1beta levels of human gingival fibroblasts stimulated by phenytoin and TNFalpha in vitro: a preliminary study. J Oral Sci.2001;43(4):255-60. doi: 10.2334/josnusd.43.255.

37. Al-Mashhadane FA, Al-Mashhadane AA, Taqa AA. Folic acid supplementation: A review of the known advantages and risks. 2018;51-9.

38. López-Sobaler AM, Aparicio A, González-Rodríguez LG, Cuadrado-Soto E, Rubio J, Marcos V, et al. Adequacy of usual vitamin and mineral intake in Spanish children and adolescents: ENALIA Study. Nutrients. 2017;9(2):131. doi: 10.3390/nu9020131.

39. Diethelm K, Huybrechts I, Moreno L, De Henauw S, Manios Y, Beghin L, et al. Nutrient intake of European adolescents: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public Health Nutr. 2014;17(3):486-97. doi: 10.1017/S1368980013000463.

40. Krasteva A, Krasteva A, Kiselova A, Panov V, Krastev Z. Oral lesions and clinical medicine. Medinform;2018. (in Bulgarian).

41. Weingärtner J, Lotz K, Fanghänel J, Gedrange T, Bienengräber V, Proff P. Induction and prevention of cleft lip, alveolus and palate and neural tube defects with special consideration of B vitamins and the methylation cycle. J Orofac Orthop. 2007;68(4):266-77. doi: 10.1007/s00056-007-0701-6.

42. Wang H, Li L, Qin LL, Song Y, Vidal-Alaball J, Liu TH. Oral vitamin B12 versus intramuscular vitamin B12 for vitamin B12 deficiency. Cochrane Database Syst Rev. 2018;3(3):CD004655. doi: 10.1002/14651858.CD004655.pub3.

43. Yaman M, Çatak J, Uğur H, Gürbüz M, Belli I, Tanyıldız SN, et al. The bioaccessibility of water-soluble vitamins: A review. Trends Food Sci Technol. 2021;109:552-63. doi: 10.1016/j.tifs.2021.01.056.

44. Pontes HA, Neto NC, Ferreira KB, Fonseca FP, Vallinoto GM, Pontes FS, et al. Oral manifestations of vitamin B12 deficiency: a case report. J Can Dent Assoc. 2009;75(7):533-7.

45. Marshall TA, Levy SM, Broffitt B, Warren JJ, Eichenberger-Gilmore JM, Burns TL, et al. Dental caries and beverage consumption in young children. Pediatrics. 2003;112(3 Pt 1):e184-91. doi: 10.1542/peds.112.3.e184.

46. Hugar SM, Dhariwal NS, Majeed A, Badakar C, Gokhale N, Mistry L. Assessment of vitamin B12 and its correlation with dental caries and gingival diseases in 10- to 14-year-old children: A cross-sectional study. Int J Clin Pediatr Dent. 2017;10(2):142-6. doi: 10.5005/jp-journals-10005-1424.