

# Nutrition, dental caries and periodontal disease: a narrative review

Philippe P. Hujoel<sup>1,2</sup> and Peter Lingström<sup>3</sup>

<sup>1</sup>Department of Epidemiology, School of Public Health, University of Washington, Seattle, WA, USA; <sup>2</sup>Department of Oral Health Sciences, School of Dentistry, University of Washington, Seattle, WA, USA; <sup>3</sup>Department of Cariology, Institute of Odontology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

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## Abstract

**Aim:** To provide a narrative review of the role of macro- and micronutrients in relation to dental caries, gingival bleeding and destructive periodontal disease.

**Materials & Methods:** This review is based on systematic reviews (when available) and comparative human studies.

**Results:** Dental caries cannot develop without the presence of dietary fermentable carbohydrates, in particular sugar. The susceptibility to develop caries in the presence of carbohydrates may be influenced by genetics and micronutrients such as vitamin D. Gingival bleeding and destructive periodontal disease are sensitive markers to both abnormalities in macronutrient content (excessive carbohydrates or poly-unsaturated fat intake, deficient protein intake) and micronutrient intake (e.g. vitamin C and B12).

**Conclusion:** Dental caries and periodontal diseases are a sensitive alarm bell for an unhealthy diet, which predicts the future onset of the diseases of civilizations.

Key words: dental caries; gingivitis; nutrition; periodontal disease; periodontitis

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Dietary recommendations have changed substantially. In the past, high-carbohydrate diets were recommended as heart-friendly. In 2002, sugary items were still recommended as heart-healthy snacks because they were free of saturated fats (National Cholesterol Education Program, 2002). Such dietary recommendations are quickly becoming a thing of the past. The *American Heart Association* and the *World Health Organization* recommended restricting sugar intake in 2009 and 2015,

respectively (World Health Organization, 2015). The *American Diabetes Association* agreed on the recommendation of a low-carbohydrate diet in 2008 (American Diabetes 2008). The Food and Drug Administration in United States (Rabin 2015) and the most recent US Dietary Guidelines specifically recommended a restriction of not only added sugars, but also refined grains (McGuire 2016). Similar dietary recommendations have also been seen in Europe in countries such as Sweden. The Nordic Nutrition Recommendations have in their latest update recommended limiting the intake of added sugars from sugar-sweetened beverages and sugar-rich foods to reduce the risk diseases such as diabetes, weight gain and dental caries. These guidelines also clarify that a limitation of such products is necessary to

ensure an adequate intake of essential nutrients and dietary fibre (NNR 2014). Such dietary recommendations provide a starting point to an optimum diet for preventing dental caries and improving periodontal health.

The basic science on nutrition and dental caries is simple as refraining from carbohydrates when consumed in solid or liquid form translates into an absence of dental decay (Hujoel 2009). It has historically been seen that populations living on a diet low in carbohydrates develop dental caries to a very low extent (Humphrey et al. 2014). In contrast, individuals living on high-carbohydrate diets, such as the overwhelming proportion of our current global population, have a high prevalence of dental caries. Dietary carbohydrates are the necessary fuel

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for creating dental caries. The fermentation of these dietary compounds by the cariogenic microorganisms leads to the formation of fermentation end products which may lead to tooth destruction. The engine that produces dental caries stalls when cereals and sugars are withdrawn from the diet.

The discussion on nutrition and periodontal disease is more complex. There are no simple modifications of micro- or macronutrient intake that will fully prevent or arrest periodontal disease. Periodontal diseases in addition are not only influenced by malnutrition (either micro- or macronutrients), but also by other factors such as oral hygiene, tobacco smoking and genetics (Newman et al. 2015).

The aim of this review is to provide a narrative overview on the role of nutrition for the prevention and treatment of dental caries and periodontal disease. It is based on a search for systematic reviews focused on macronutrients (fats, carbohydrates and proteins) and micronutrients (minerals and vitamins) and other articles as listed in Table 1. Fluoride is not considered here as it is not a necessary nutrient.

### Nutrition versus Diet

Nutrition is the process of taking in food and its use for growth, metabolism and repair. Consideration on its qualities, composition and effect on health have by tradition primarily focused on an optimal intake of carbohydrates, fat, proteins, vitamins and minerals. The nutritional aspects are different from the dietary. The

diet is the kind of food that a person habitually eats. "Nutrition" refers to the sum of biological processes as it relates to dietary intake. This distinction is for many medical conditions, including dental caries and periodontal disease, important in relation to disease development and progression.

The roles of functional foods in relation to health and disease have lately been added to discussion and yields increased attention from both a medical and dental perspective. There is an ongoing search to identify functional foods and their components to prevent dental caries (Gazzani & Grusak 2012, Spratt et al. 2012). Among different substances, the evidence regarding plant extracts and their polyphenol content is extensive. This includes green tea, which is known to have a high content of catechins. Also black tea and semi-fermented oolong tea are together with cocoa and red grape seeds known to possess similar characteristics. Other food products claimed to have antimicrobial properties are fruits and berries, Milk and milk products can also from a broader dental perspective be considered as having extra health benefits due to their content of calcium, phosphate and different protein structures. The different actions by functional foods include a number of antibacterial activities, reduction in dental biofilm acidogenicity, effect on adhesive properties and enhanced remineralization. Also probiotics is today explored as a strategy both against caries and periodontal diseases. Products containing naturally or added, different health-promoting

microorganisms are under investigation and await controlled trial evidence prior to recommendations.

### Dental Caries

Nutrition may act both systemically and locally in relation to dental caries. An optimal intake in energy and nutrients to achieve an optimal tooth formation process is important. This period starts during foetal stage and is to a large extent completed around six years of age. Nutritional deficiencies disturb the mineralization process resulting in a tooth that more easily develops caries (Alvarez 1995). Not only the teeth but also the salivary gland formation and function should be regarded from this respect as these organs are known to be sensitive to nutritional changes (Johansson & Widerström 1994).

The caries process is a consequence of the intake of fermentable carbohydrates including sucrose, glucose, fructose, lactose, maltose and starch. These fermentable carbohydrates may have both local and systemic effects on dental caries. The local effects are typically described as the result of carbohydrates being broken down by microorganisms in the dental biofilm, which release acidic end products of which lactate and acetate play a major role. The variation in acid production in a caries-promoting environment is small among the different fermentable carbohydrates. Thus, the local dietary effects are dependent on what is consumed at a specific time point, and influenced by many factors influencing the intra-oral environment such as overall dietary habits, biofilm composition, saliva and fluoride. Its magnitude will therefore vary from one individual to another, but also from one tooth to another. The enamel will start to demineralize when exposed to fermentable carbohydrates if the pH during the bacterial fermentation process is lowered below the critical level of pH 5.5–5.7. This occurs after consumption of most sugars found in candy, soft drinks, fruit juices, or the sugars added to coffee or tea. The dentine or root surfaces of a tooth, when not covered by enamel, have due to their lower mineral content a higher critical pH (around pH 6.2).

Table 1. Key references on nutrition and oral health ordered by focused publication date

Author	Systematic reviews or key studies
Gustafsson et al. (1954)	Sugar intake frequency and dental caries
Leggott et al. (1986, 1991)	Vitamin C and gingival bleeding
Lingström et al. (2000a,b)	Starch and dental caries
Krall et al. (2001) Dietrich et al. (2005)	Vitamin D and periodontal health/tooth loss
(Nyvad 2003)	Sugar and dental caries
Hujoel (2009)	Dietary carbohydrates and gingival inflammation
Spratt et al. (2012)	Functional foods and gingivitis and dental caries
Hujoel (2013)	Dental caries and vitamin D
Moynihan & Kelly (2014)	Sugar and dental caries
Salam et al. (2015)	Dental caries and vitamin B6
Southward (2015)	Dental caries and vitamin K
Sheiham & James (2015)	Diet and dental caries
Zong et al. (2016)	Vitamin B12 and destructive periodontal disease

Complex carbohydrates found in whole foods such as potatoes, rice, cereals and bread contribute to the caries of the dentine and the cementum (Lingström et al. 2000a,b). The relationship between fermentable carbohydrates and dental caries may therefore change during lifetime as the root surface routinely become exposed with increasing age. It therefore makes sense to distinguish between the dietary recommendations given to children and adolescents in comparison with elderly.

### Advice for Pregnant Women and Mothers of Young Children

Tooth quality is known to be of importance for the development of caries (Vargas-Ferreira et al. 2015). Most organizations, including the World Health Organization (WHO), agree that vitamin D deficiency may lead to dental hypoplasia. The hardness of bones and teeth is largely a function of nutrition from the time of conception to puberty. Mineralization of teeth depends on a large number of micronutrient factors. Vitamin D, calcium and phosphate play a major role (Hujuel 2013). Other vitamins may play equally important roles but have not been as extensively studied. For instance, controlled trial evidence has suggested a role for vitamin B6 in dental caries prevention (Salam et al. 2015). Vitamin K appears to be another promising candidate in the protection against dental caries (Southward 2015). The aim of this review is not to suggest that dietary recommendations should focus on any single micronutrient such as vitamin D, but instead to point out that proper tooth mineralization is favourably influenced by foods rich in mineralizing factors such as dark-green leafed vegetables, cheese, milk, cod-liver oil, oyster mushrooms, eggs and certain species of wild salmon (Lu et al. 2007). It is true that vitamin D can be particularly challenging to obtain with whole foods for people who avoid the sun (Gillie 2010). For strict vegans (whom avoid milk), vitamin D supplements could be taken in combination with minerals, as either vitamin D alone or minerals alone have not been shown to be provide systemic benefits (Dawson-Hughes et al. 1997,

Boonen et al. 2007). The effectiveness of supplements as opposed to whole foods has not been adequately evaluated in this regard. Caution is required given the often disastrous adverse health effects of supplementation trials observed for vitamins and minerals (Bjelakovic et al. 2007).

### Dental Caries in Infants, Children and Adolescents

The knowledge that sweets cause dental caries goes back thousands of years with Aristotle referring to how sweet figs decay the teeth (Burgess 1988). During the 20th century, many controlled experiments demonstrated that sugar restriction – not elimination – dramatically reduced the caries incidence. Sugar restriction in the late 1920s was found to prevent dental decay which was relevant (Bunting et al. 1930) as a majority of children during this time period were suffering from dental decay. Around the same time, paediatricians who took care of diabetic children noticed similar dramatic effects of low-carbohydrate diets on preventing dental caries (Boyd & Drain 1928, Boyd et al. 1929).

An inconvertible truth was established: simple sugars cause dental decay of the enamel. One of the largest controlled dietary studies subsequently reported that even small amounts of additional sugar in the diet spike dental caries rates (Gustafsson et al. 1954). Repairing existing caries lesions with dietary interventions was demonstrated to be feasible. These results on reversing dental caries were published in the premier journal *Science* and authored by the Founding Dean of the University of California Los Angeles Dental School (Sognnaes 1941). Nonetheless, such findings rarely gained popularity in the dental profession.

The role of sugar in relation to dental caries was often dismissed based on ecological correlations (Sheiham & James 2015). A decrease in caries prevalence has been seen in most parts of the modern industrialized society in spite of a remaining high sugar consumption (Nyvad 2003). This increased tolerance against sugar frequency was attributed to fluoridated toothpaste (Duggal et al. 2001; Marinho et al. 2003; Zero 2004).

The undue influence of the sugar industry may have played a role in promoting fluoride and oral hygiene as the solution to dental caries. (Kearns et al. 2015). As soon as studies came out that dental decay was caused by sugar, the sugar industry started to advertise with a message they have not deviated from since: “[t]he remedy is to keep the teeth clean.” This 1929 message was slightly updated in a 2008 Coca-Cola advertisement: “Dental hygiene is the key! Make sure you look after your teeth by brushing regularly” (Burke 2009). The simple narrative that dental decay is caused by plaque growing on teeth, an infection, and that this infection can be eradicated with dental hygiene, became enshrined in the dental consciousness. A similar argument has during the years been seen in relation to smoking. Such advertisements from sugar and tobacco companies have a seductive biological plausibility argument – especially if one is addicted – but had disastrous consequences as they are unproven and untrue.

The reported effectiveness of strategies to counter the adverse effect of sugar and other carbohydrates is often exaggerated and based on weak evidence. The problem with advocating ineffective or marginally effective preventive measures to individuals susceptible to dental caries is that it results in a situation where one continues what is now generally accepted as an unhealthy diet under the mistaken impression that preventive strategies are effective. For those people for whom the pleasures of life need to include sugar, it is important to prioritize their efforts on combatting the harmful effects of sugars. This can be achieved by ensuring that they first and foremost remain focused on the caries-preventive agent – fluoride – that is widely recognized as effective.

### Caries and Diet – A Complex Relationship

Eating dietary carbohydrates does not imply that dental caries will develop. Not only what we eat, but also the behavioural aspects and circumstances related to consumption play a role. This was first demonstrated in the Vipeholm study where

one and the same sugary item resulting in large variations in caries prevalence depending on whether it was consumed at or in between meals (Gustafson et al. 1954). This is applicable also for today's generation where a variation in intake of one and the same intake frequency may have varying impact on the outcome of caries. The composition of dietary intake of the modern human population has changed dramatically.

Lately, also sugar amount has been put into focus and a new understanding of the relationship between sugars and dental caries has been suggested. The recommendation of sugar intakes  $\leq 10\%$  of the daily energy intake (E) does not, due to the still high remaining caries burden internationally, suffice, and a daily intake of  $< 5\%$  E has instead been suggested (Moynihan & Kelly 2014, Sheiham & James 2015).

The likelihood that a person consuming dietary carbohydrates will develop caries depends also on caries-preventive factors, including genetics, which may counteract for negative dietary habits (Bretz et al. 2006). The final outcome is an end result of the balance between caries-promoting and protective factors.

### Periodontal Disease and Nutrition

Development of dental caries was regarded as a telltale sign of an unhealthy diet – a diet high in carbohydrates can lead to diabetes and cardiovascular disease later in life (Hujoel 2009). The converse, however, does not necessarily hold true. The absence of dental caries does not necessarily imply an overall healthy diet. A carbohydrate-free diet, a diet providing a freedom from dental caries, can be decidedly unhealthy in relation to other oral and medical condition, including periodontal disease. For instance, a carbohydrate-free diet in which vegetable oils, a substance high in omega-6 fatty acids, are the dominant source of fats has been associated with an increased risk of myocardial infarction and death from cardiovascular disease (Ramsden et al. 2010, 2013). If one looks at teeth as a window to overall systemic health, an absence of both dental caries and gingival bleeding in the absence of oral hygiene could be

regarded as a potentially sensitive marker for an overall healthy diet.

The maintenance of periodontal health depends on the ability to have a nutrition, which is optimal both with respect to macro- and micronutrients.

### Micronutrients

Until at least the middle of the 18th century, periodontal disease was considered a manifestation of scurvy, a deadly condition. This story remains relevant today, as the CDC reported in 2009 that 7% of the US population has a vitamin C deficiency (Schleicher et al. 2009). Metabolic chamber experiments have shown that vitamin C depletion in humans leads to profuse gingival bleeding, regardless of oral hygiene (Jacob et al. 1987). Dietary supplementation of vitamin C reverses the gingival bleeding within days and without changes in the alleged infectious causes of periodontal disease (Leggott et al. 1986, 1991). We do not imply here, or anywhere else for that matter, that vitamin C supplements or any supplementation products are needed for periodontal health.

There is increasing evidence that even subtle micronutrient deficiencies may adversely impact periodontal health. A randomized control trial on the supplementation of nutrition with a fruit, vegetable and berry juice extract among an apparently healthy study population showed positive effects on periodontal health with a reduction in bleeding in a 2-month period (Chapple et al. 2012). Vitamin D has similarly been related to gingival inflammation (Dietrich et al. 2005), and vitamin D supplementation combined with calcium has been shown to reduce tooth loss (Krall et al. 2001).

One unanswered question with respect to nutrition and periodontal health is the compatibility of veganism with periodontal health, with veganism defined as those refraining from consuming animal products, including eggs, dairy and other animal-derived substances. There is a risk for vitamin B12 deficiency with such a diet, which may lead to irreversible and serious neural damage. Identifying those individuals with a vitamin B12 deficiency can be challenging. It is fascinating from this

perspective that a prospective cohort study has identified that low serum B12 levels were associated with a worsening of the periodontal status of teeth and an increased tooth loss rate (Zong et al. 2016). This study may yet provide another clue that periodontal health is a most sensitive indicator of poor nutritional status.

### Macronutrients

#### Carbohydrates

Sugar and carbohydrates are known not only increase the risk for dental caries, but also for gingival bleeding. Seven controlled trials documented an increase in gingival bleeding with an increased intake of sugars (Hujoel 2009, Woelber et al. 2016). These increases in gingival bleeding have been observed even among dental hygienist and dental students who presumably had excellent oral hygiene routines. An interesting study with respect to the role of refined foods in gingival bleeding was performed where people lived on a Stone Age diet for 4 weeks with no access to toothbrushes and dental floss. Some dental professionals expected that these individuals' gingival condition would get worse, but surprisingly the opposite occurred. Despite the increases in dental plaque, gingival bleeding decreased (Baumgartner et al. 2009).

#### Fats

The type of fats in the diet is related to both overall health and periodontal health. Omega-6 fats are predominantly present in vegetable oils, which were promoted as improving cardiovascular health. These claims of improved cardiovascular health were never demonstrated in terms of prevention of myocardial infarctions or deaths. A recent systematic review of clinical trials reported the opposite. An increased intake of omega-6 fatty acids was associated with an increased risk for non-fatal myocardial infarction and coronary heart disease deaths (Ramsden et al. 2010, 2013). A high vegetable oil intake has also been shown to be associated with an increased incidence of periodontal disease progression (Iwasaki et al. 2011) providing yet another reason why poor periodontal health



and cardiovascular health may be related. The recommendation to restrict vegetable fats for periodontal health is currently in conflict with the US Dietary guidelines (McGuire 2016).

### Proteins

The gingival tissue has one of the highest turnover rates in the human body, and proteins are keys to maintaining such a turnover. One of the symptoms of Kwashiorkor, severe protein malnutrition, is tooth loss and periodontal lesions (Pindborg et al. 1967, Seck & Moreau 1982).

### Summary

Current evidence suggests that the optimum diet for health is a low-carbohydrate diet, high in non-vegetable fats, high in micronutrients and containing sufficient protein. Such a diet can with a high degree of certainty be reported as preventing dental caries and improving periodontal health. Such a dietary recommendation is today considered an acceptable diet for both diabetics and pre-diabetics.

A low-carbohydrate diet high in non-vegetable fats is incompatible with today's dietary recommendations and needs to be discussed with the physician of the patient. An additional modification to the US dietary guidelines with the aim to reduce the overall cariogenic sugar intake would be to limit fruit intake to low-sugar fruits such as avocados, strawberries and raspberries. Further modifications to this diet such as increased restriction of carbohydrates or an avoidance of vegetable fats need for each individual to be discussed on an individual basis.

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## Address:

Philippe P. Hujoel  
 Oral Health Sciences  
 School of Dentistry  
 University of Washington,  
 BOX 357475, Seattle  
 WA 98195-7475  
 USA  
 E-mail: hujoel@uw.edu

**Clinical Relevance**

*The scientific rationale for the study:* To report the effects of nutrition on dental diseases.

*Principal findings:* The harmful dental effects of malnutrition including high-carbohydrate diets have been well documented.

*Practical implications:* Patients should be informed how poor nutrition can lead to poor dental and general health. Guidance on primary nutritional prevention may be challenging to implement in a dental setting due to the confusing public health messages on nutrition, the

lack of authority of the dental profession in the area of nutrition and the addictiveness of dietary carbohydrates.