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INVITED MEDICAL REVIEW

Nutrition and health: guidelines for dental practitioners

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Good nutrition is vital to overall health, and poor diet and a sedentary lifestyle are major causes of morbidity and mortality worldwide. Nutritional factors are implicated in many oral and systemic diseases and conditions, including obesity, hypertension, dyslipidemia, type II diabetes, cardiovascular disease, osteoporosis, dental caries and some cancers including oral cancers. This review focuses on the evidence for the relations between key nutritional factors and health. Energy intake is related to body weight and obesity, highlighting the importance of lower-energy diets and regular physical activity for body weight maintenance and for preventing obesity. Evidence is presented for the health benefits of high quality carbohydrates, such as whole grain products, and fruits and vegetables, in reducing the risk of cardiovascular disease and cancer. The adverse effects of sugar, sweetened beverages, and *trans* and saturated fats on several diseases including caries, diabetes and cardiovascular disease are described. The health benefits of unsaturated fats, antioxidants, B vitamins and vitamin D in cardiovascular disease, periodontitis, cancer, and other conditions are documented. Both benefits and harmful effects of dairy product intake on health are discussed. Based on the evidence, nutritional guidelines are provided, as well as key recommendations for preventing obesity. Dentists can play a critical role in motivating and enabling healthy food choices.

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Dentists contribute to knowledge about nutrition and health

Over 29,000 dentists have been directly contributing to research on the relation of diet to health since 1986, through their participation in the Health Professional's Follow-up Study (HPFS) conducted at Harvard School of Public Health. Participants have completed detailed dietary questionnaires every four years along with other questionnaires about lifestyle and medical and oral health history, and many have contributed blood samples. This research has provided unique information on the prevention of heart disease, many cancers, oral precancer, periodontal disease, and other important illness. Several manuscripts using the HPFS data are referenced in this review article. More details of the study and description of the research findings can be found at the Health Professional's Follow-up Study website: http://www.hsph.harvard.edu/hpfs

Introduction

Good nutrition is vital to good health. Poor diet and a sedentary lifestyle are major causes of morbidity and mortality worldwide. Nutritional factors are implicated in several oral and systemic diseases and conditions, including overweight and obesity, hypertension, dyslipidemia, type 2 diabetes, cardiovascular disease, osteoporosis, dental caries, gastrointestinal disorders and most cancers including oral cancers.

One of the main challenges in the prevention of most chronic diseases is reducing obesity, which is now recognized as one of the major public health problems worldwide. It is estimated that one billion individuals in the world are overweight and at least 300 millions are obese (World Health Organization (WHO) (2003). Obesity is the leading cause of many chronic conditions (National Institute of Health, National Heart, Lung, and Blood Institute, 1998), and the mortality rate is 2–3 times higher in the obese individuals compared with

normal weight adults (Adams *et al*, 2006). A healthy diet is crucial for preventing and reducing obesity. Lack of physical activity is a major determinant of obesity and also a risk factor for many conditions.

This manuscript summarizes the evidence for the role of physical activity and intake of total energy (calories), specific foods and micronutrients in promoting oral as well as overall health and in preventing chronic diseases.

Key relations between nutrition and health

Most people consume a wide variety of foods, with a combination of many nutrients and the dietary patterns often change over time. This makes it challenging to ascertain the health impact of any one nutrient or food. However, several foods and nutrients have well-established relationships to specific conditions as described below.

Energy intake, physical activity and obesity

Maintaining body weight within normal ranges is important for well being, as obesity is a risk factor for hypertension, type 2 diabetes, coronary heart disease (CHD), stroke, gallbladder disease, osteoarthritis, sleep apnea, respiratory problems and some types of cancer (including endometrial, breast, prostate, pancreatic, kidney and colon) (National Institute of Health, National Heart, Lung, and Blood Institute, 1998). Obesity is also related to several aspects of oral health, such as xerostomia, caries and periodontitis (Mathus-Vliegen *et al*, 2007). Adipose tissue is also a source of inflammatory cytokines. Hence, increasing body fat may increase the likelihood of an active host inflammatory response in periodontitis (Shuldiner *et al*, 2001). Several cross-sectional studies have shown associations between obesity and periodontitis (Saito *et al*, 1998; Ritchie *et al*, 2002; Pischon *et al*, 2007).

Physical activity also independently reduces the risk of several diseases including cardiovascular disease, type 2 diabetes mellitus, osteoporosis, and colon and breast cancer (Haskell *et al*, 2007b), even among normal weight individuals. Increased physical activity has been also associated with lower levels of periodontal disease in two recent longitudinal studies, independent of obesity (Merchant *et al*, 2003; Al-Zahrani *et al*, 2005).

Body weight is determined primarily by the balance between energy (calorie) consumption and expenditure (activity); for weight maintenance, energy consumption should equal expenditure. Weight reduction can be achieved by decreasing energy intake and/or increasing physical activity, while the reverse would lead to weight gain. Most studies show that to maintain a healthy body weight (within normal ranges) and for weight-loss, individuals should consume low-energy diets and engage regularly in physical activity (Anderson *et al*, 2001; Wing and Phelan, 2005; Galani and Schneider, 2007; Haskell *et al*, 2007b). In a recent large randomized trial, differences in the percentage of energy from fat, carbohydrate and protein did not affect body weight over a 2-year period (Sacks *et al*, 2009). Recommendations for energy intake are based on each individual's weight, height and activity level [for calculating energy requirements, refer to the Dietary Reference Intakes report from the Institute of Medicine (Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition board, Institute of Medicine, 2005)]. The American College of Sports Medicine and the American Heart Association's recommendation for healthy adults is to engage in at least 30 min of moderate-intensity aerobic activity on 5 days of every week or at least 20 min of vigorous-intensity aerobic activity on 3 days of the week (Haskell *et al*, 2007a). Even though this level of physical activity has clear benefits for disease prevention, some individuals will need greater amounts for weight control.

Carbohydrate intake

The specific percentage of calories from carbohydrate in the diet does not appear to be an important determinant of weight gain or risk of disease, but the quality of carbohydrates is important. High quality carbohydrates, such as whole grain products and fruits and vegetables, have positive health benefits. These foods are good source of fiber, minerals such as potassium, magnesium, zinc and selenium, and vitamins such as vitamin A, K, C and the B vitamins. Studies have found that diets rich in whole grain products reduce the risk for diabetes (Haskell *et al*, 2007b; de Munter *et al*, 2007; Barclay *et al*, 2008) and heart disease (Anderson *et al*, 2000; Barclay *et al*, 2008). In addition, whole grain products, especially if not milled into fine flour, and fruits and vegetables tend to have low glycemic indexes, which prevent a quick rise in blood sugar. Diets rich in high-glycemic-index foods, such as white bread and potatoes, lead to a quick and strong increase in blood sugar levels, which then stimulates a large release of insulin, which in turn signals cells to absorb blood sugar for energy or storage. As a result, blood sugar declines suddenly and steeply and may lead to an increase in food intake. Meta-analyses of clinical trials also show that diets high in refined carbohydrates and sugar increase the levels of triglycerides and decrease the levels of HDL cholesterol (Anderson *et al*, 2004; Thomas *et al*, 2007). Several studies now show that such diets increase the risk for overweight (Maki *et al*, 2007; Thomas *et al*, 2007; Livesey *et al*, 2008), diabetes (Barclay *et al*, 2008) and heart disease (Beulens *et al*, 2007; Barclay *et al*, 2008). Some foods, low in glycemic index, include coarsely ground whole grain bread, beans and legumes, nuts, and high-fiber fruits and vegetables.

Total carbohydrate intake has not been related to periodontitis. However, one large cohort study of male US health professionals showed an inverse association between whole-grain intake and periodontitis (Merchant *et al*, 2006).

Fermentable carbohydrates result in acid production by cariogenic plaque bacteria and lowering of the plaque pH leads to demineralization. Sucrose is the most cariogenic sugar because it can form glucan that enables firm bacterial adhesion to teeth (Tinanoff and Palmer, 2003). The frequency of sugar intake is a major determinant of caries risk (Gustafsson *et al*, 1954).

Caries risk is the greatest if sugar is consumed at high frequency, more so when the sugar is in a form that is retained in the mouth for long periods of time. The effect of sugar or other carbohydrates on caries could be reduced by fluoride (ingested or topical) and good oral hygiene, but a reduction in sugar should be the primary approach as this has many health benefits.

Sugar and sweetened beverages intake. Regular consumption of sugar-sweetened beverages has been associated with increased energy consumption in children (O'Connor *et al*, 2006) and with the risk of obesity in children and adults (Ludwig *et al*, 2001; Malik *et al*, 2006, 2009; Wolff and Dansinger, 2008). Short intervention trials in children and adolescents to decrease sugar-sweetened consumption resulted in decreases in BMI in those with higher BMI at baseline (Ebbeling *et al*, 2006; Sichieri *et al*, 2009) and increases in lean body mass (Albala *et al*, 2008). Regular consumption of sugar-sweetened beverages has also been associated with increased risk of type II diabetes (Schulze *et al*, 2005; Palmer *et al*, 2008) and CHD (Fung *et al*, 2004, 2009). Consumption of soft drinks containing sugar is also related to increased caries prevalence and incidence (Lim *et al*, 2008).

Fiber intake. Several large, longitudinal epidemiological studies have found an inverse relation between dietary cereal fiber intake and risk of cardiovascular disease (Rimm *et al*, 1996; Pereira *et al*, 2004). In clinical trials, increased dietary fiber intake also reduces blood pressure (Streppel *et al*, 2005; Whelton *et al*, 2005) and total and LDL cholesterol levels (Brown *et al*, 1999). Also, in several large longitudinal studies, fiber intake from whole grain products has been associated with the risk of diabetes (Krishnan *et al*, 2007; de Munter *et al*, 2007; Schulze *et al*, 2007). Furthermore, clinical trials show that diets rich in whole grains result in improved insulin sensitivity in obese subjects (Rave *et al*, 2007). In addition, fiber consumption can reduce the occurrence of diverticular disease (Aldoori *et al*, 1998; Aldoori and Ryan-Harshman, 2002) and constipation (Hongisto *et al*, 2006). A pooled analysis of case–control studies supports an inverse association between dietary fiber and endometrial cancer (Bandera *et al*, 2007). However, for colon cancer, the evidence is not clear. Large epidemiological studies do not show any association of dietary fiber and colon cancer (Fuchs *et al*, 1999; Park *et al*, 2005; Schatzkin *et al*, 2007). Also, in clinical trials, higher intake of fiber has not reduced the occurrence of colorectal adenomas (Jacobs *et al*, 2006).

Fruits and vegetables intake. A diet rich in fruits and vegetables is associated with reduced risk of cardiovascular disease. Results from several large longitudinal studies show that individuals consuming five or more servings per day of fruits and vegetables significantly reduce their risk of cardiovascular disease (Hung *et al*, 2004; Dauchet *et al*, 2006; He *et al*, 2006, 2007). Clinical trials also show that diets rich in fruits and vegetables significantly reduced blood pressure (Appel *et al*, 1997).

With respect to cancer risk, the evidence is inconsistent. Case–control studies show an inverse association between fruits, vegetables and several other cancers (esophagus, lung, stomach and colorectum). Cohort studies have suggested a protective effect of fruits on bladder cancer (Riboli and Norat, 2003), while a very large cohort study did not find a protective effect of five or more servings of fruits and vegetables on total cancer risk (Hung *et al*, 2004). Both case–control and cohort studies show that high intake of fruits and vegetables are inversely associated with oral precancer (Gupta *et al*, 1998; Morse *et al*, 2000; Maserejian *et al*, 2006) and cancer (Gridley *et al*, 1990; Levi *et al*, 1998; Boeing *et al*, 2006; Pavia *et al*, 2006). Fruits show a stronger and more consistent inverse association with oral cancer; for vegetables, the strongest inverse association is seen for tomatoes (De Stefani *et al*, 2000). A meta-analysis of cohort studies on gastric cancer showed that fruits and vegetable intake was associated with lower incidence, but it was not associated with mortality (Lunet *et al*, 2005). These differences in results may be explained by the diversity of compounds, such as vitamins and minerals, present in different fruits and vegetables and their differential effects on certain types of cancer. This is discussed further in the Vitamins and minerals intake section.

Fat intake

Diets high in fats have been believed to be linked to obesity and chronic diseases (Bray and Popkin, 1998; Drewnowski, 2007; Mendoza *et al*, 2007), but the overall evidence does not support a relation between the percentage of fat in the diet and body weight or risks of cardiovascular disease or cancer (Hu and Willett, 2002; World Cancer Research Fund (WCRF)/American Institute for Cancer Research, 2007). A large randomized trial showed that total fat intake was unrelated to long-term control of body weight (Howard *et al*, 2006a), risk of cardiovascular disease (Howard *et al*, 2006b) or risk of cancer (Beresford *et al*, 2006; Prentice *et al*, 2006). Also, as noted above, in a large randomized trial, the percentage of fat was not related to body weight (Sacks *et al*, 2009). As with carbohydrates, the quality of fat is more important than the total amount of fat consumption.

Trans *and saturated fat intake*. Epidemiological studies show that the consumption of unsaturated fat decreases the risk of heart disease, whereas the consumption of *trans* fat increases the risk (Willett, 1993; Hu *et al*, 2001). The magnitude of this association is considerably stronger for *trans* fat compared with saturated fat consumption (Willett, 2006), and when saturated fat is compared with the same level of calories from carbohydrate, the difference in risk of heart disease is minimal. In controlled feeding studies, diets high in *trans* fat significantly increase LDL and VLDL cholesterol and significantly decrease HDL cholesterol compared with mono- and poly-unsaturated fats. Compared with carbohydrate, saturated fat increases both LDL and HDL cholesterol (Mensink *et al*, 2003). High levels of LDL

and VLDL cholesterol and low levels of HDL cholesterol are associated with increased risk of cardiovascular disease (Stamler *et al*, 2000; Anum and Adera, 2004). Furthermore, *trans* fat intake is positively associated with markers of systemic inflammation in women (Mozaffarian *et al*, 2004), suggesting a uniquely adverse cardiometabolic effect via pathways linked to insulin resistance (Mozaffarian and Willett, 2007). Red and processed meats are associated with an increased risk of hypertension (Steffen *et al*, 2005), CHD (Hu *et al*, 1999), and type 2 diabetes (Fung *et al*, 2004). It was estimated from the Nurses' Health Study that replacing only 5% of the energy from saturated fats and 2% of *trans* fat with unsaturated fats would reduce the risk of coronary disease by 42% and 53%, respectively (Hu *et al*, 1997).

There is not enough evidence to relate total fat, *trans* or saturated fat consumption with increased risk for most cancer. However, epidemiological evidence suggests that diets rich in animal fat increase the risk of breast cancer in young women (Cho *et al*, 2003), while diets rich in monounsaturated fats (mainly in the form of olive oil) may reduce this risk (Sieri *et al*, 2004). Similar results have been found with some other cancers. Red meat consumption has been associated with an increased risk of colorectal cancer (Larsson and Wolk, 2006; Sandhu *et al*, 2001; WCRF, 2007).

Unsaturated fat intake. While the consumption of *trans* and saturated fat may increase the risk of many chronic diseases, the opposite is true for the consumption of mono- and poly-unsaturated fat. Epidemiological and clinical studies show that unsaturated fat consumption can lower blood pressure, improve lipid levels (reduce LDL and total cholesterol and increase HDL cholesterol), and reduce cardiovascular risk (Willett, 1993, 2006; Ascherio *et al*, 1996; Hu *et al*, 2001, 2002, 2003; Mensink *et al*, 2003; Appel *et al*, 2005).

Several epidemiological studies also relate the consumption of fish to a lower risk of heart disease, especially sudden cardiac death (Albert *et al*, 2002; He *et al*, 2002). Fish is rich in the essential omega-3 fatty acids. Meta-analysis of observational studies showed that individuals consuming fish have a reduction of about 20% in the risk of fatal CHD and 10% in total CHD compared with those consuming little or no fish (Whelton *et al*, 2004), and eating fish once per week appears to reduce death from CHD by about 15% (He *et al*, 2004). Clinical trials using fish oil have also shown a reduction in fatal CHD and sudden death (Harper and Jacobson, 2005). Omega-3 fatty acids could also alter the inflammatory process in periodontitis (Kesavalu *et al*, 2006).

Nuts are also rich in mono- and poly-unsaturated fatty acids as well as fiber and micronutrients. Several epidemiological studies show that regular nut consumption is associated with lower risk of CHD (Hu and Stampfer, 1999). Based on the data from the Nurses' Health Study, substituting saturated fat with nuts would result in 45% reduction in the risk of CHD (Hu and Stampfer, 1999). Clinical trials have also shown that various forms of nuts decrease LDL cholesterol (Gebauer *et al*, 2008) and triglycerides (Alper and Mattes, 2003), and increase HDL cholesterol (Sheridan *et al*, 2007), with no effect on body weight if total calories are kept the same (Hollis and Mattes, 2007; Mattes *et al*, 2008).

Antioxidant intake

Antioxidants are substances that prevent or reduce damage caused by reactive oxygen species (ROS) or reactive nitrogen species. Certain vitamins (especially vitamins C and E) and minerals (selenium) act as antioxidants and may protect against tissue damage, thus, reducing the risk of heart disease and cancer. Many of these antioxidants are present in fruits and vegetables; therefore, the role of individual antioxidants on preventing chronic diseases is not very clear.

A pooled analysis of nine cohort studies that included information on intake of vitamin E, carotenoids and vitamin C found that only a high consumption of vitamin C (>700 mg day^{-1}) was associated with lower risk of CHD (Knekt *et al*, 2004). A meta-analysis that included 11 randomized control trials of supplementation with vitamins E and C, beta-carotene, selenium, folate, vitamin B-6 or vitamin B-12 did not show a protective effect of any of these antioxidants on the progression of atherosclerosis (Bleys *et al*, 2006). The epidemiologic studies differ from the randomized trials in many ways because in the former, subjects with known CHD were excluded, whereas the randomized trials were almost all conducted among subjects with known CHD and on many medications. The Women's Health Study was conducted among primarily healthy people; although there was no overall effect of vitamin E supplements on the risk of CHD, the risk of total cardiovascular mortality was significantly reduced by 24% (Buring, 2006). Thus, the use of antioxidant supplements does not appear to be beneficial among patients with existing CHD, but the effects among apparently healthy people remain unclear.

Antioxidants could also alter the inflammatory process in periodontitis (Chapple *et al*, 2007). Vitamin C is clearly effective in preventing scurvy. Recent data from the NHANES III show an inverse association between dietary vitamin C and periodontal disease (Nishida *et al*, 2000b). In another study, serum levels of vitamin C were inversely associated with periodontitis prevalence, even among never smokers (Chapple *et al*, 2007). ROS have been associated with periodontitis, which if not buffered by sufficient antioxidants, could increase the damage to the periodontal tissue (Moynihan, 2005).

Antioxidants may also prevent certain cancer, by protecting cells from oxidative damage. However, the evidence from epidemiological and clinical studies is not clear. Several meta-analyses of prospective cohorts studies in North America and Europe have not found associations between carotenoid intake and risk of colorectal cancer (Mannisto *et al*, 2007), nor between vitamins A, C, E, and folate supplements and the risk of lung cancer (Cho *et al*, 2006), nor between alpha-carotene, beta-carotene, beta-cryptoxanthin, lutein/zeaxanthin, and lycopene and the risk of invasive

epithelial ovarian cancer (Koushik *et al*, 2006). However, epidemiological studies seem to support a role of lycopene in reducing the risk of prostate cancer (Giovannucci *et al*, 2002; Etminan *et al*, 2004). Similarly, several meta-analyses of clinical trials have not found a protective effect of vitamin C and E supplements on the treatment and prevention of cancer in the doses evaluated (Coulter *et al*, 2006) nor in the consumption of antioxidant supplements in preventing colorectal adenoma (Bjelakovic *et al*, 2006) or gastrointestinal cancers (Bjelakovic *et al*, 2008). Furthermore, a recent meta-analysis of 12 randomized clinical trials found that beta-carotene supplementation appeared to increase cancer incidence and cancer mortality among smokers, whereas vitamin E supplementation had no effect (Bardia *et al*, 2008). However, trials using β-carotene supplements showed reduced risk of oral cancers and remission of precancers with an improvement of at least one grade dysplasia in 39% and no change in 61% of patients (Garewal *et al*, 1999). Cohort and case control studies also suggest reduced risk of oral cancer among people who consumed different carotenoids (WCRF, 2007).

Selenium, a mineral antioxidant, may have a preventive role on cancer. Several meta-analyses of case–control and cohort studies suggest that selenium intake may reduce the risk of prostate cancer (Etminan *et al*, 2005) and lung cancer (Zhuo *et al*, 2004). Clinical trials also suggest a protective role of selenium supplementation in primary cancer incidence in men (Bardia *et al*, 2008) and in gastrointestinal cancer occurrence (Bjelakovic *et al*, 2008). However, a recent report from the SELECT trial on more than 35 000 individuals with vitamin E and/or selenium supplementation followed for 5.5 years did not reduce prostate cancer risk (Lippman *et al*, 2009).

Vitamins and minerals intake

B-vitamins intake. B-vitamins may reduce the risk of cardiovascular disease by ways of reducing homocysteine levels. A meta-analysis of randomized clinical trial showed clear evidence that folate and vitamin B-12 supplementation reduce blood levels of homocysteine (Homocysteine Lowering Trialists' Collaboration, 2005). Observational studies also show a reduction in the risk of cardiovascular disease in individuals with high folate and B6 intake (Rimm *et al*, 1998; Bazzano *et al*, 2006). Recent randomized trials show little benefit of folate or B-12 on risks of cardiovascular disease (Bazzano *et al*, 2006). However, these recent trials have been performed primarily in patients with existing cardiovascular disease, of relatively short duration, and some were in populations where the food supply was fortified with folate. A meta-analysis published in Lancet 2 years ago showed a clear benefit of folic acid supplementation in reducing the risk of stroke, especially in populations with lower folate intake (Wang *et al*, 2007). In addition to the effects on cardiovascular health, folic acid supplementation reduces the risk of neural tube defects and other congenital anomalies (Goh *et al*, 2006).

Calcium and vitamin D intake. Calcium and vitamin D intakes are essential for maintaining bone mass. A meta-analysis of 33 clinical studies showed a positive effect of 1000 mg of calcium supplementation on bone mass in young and premenopausal women (Welten *et al*, 1995), while another meta-analysis showed that dairy products were only beneficial in young white women (Weinsier and Krumdieck, 2000). Around menopause, when bone resorption is greater than formation, calcium supplementation does not prevent bone loss (Dawson-Hughes *et al*, 1990). However, after about 5 years postmenopause, calcium supplementation prevents further bone loss and may increase bone mass by 1.6–2% (Shea *et al*, 2004). More recently, a large, randomized-control clinical trial in 36 282 healthy postmenopausal women, the Women's Health Initiative (WHI) study, indicated that prolonged calcium and vitamin D supplementation significantly reduced bone loss at the hip (Jackson *et al*, 2006). Despite these apparent benefits of calcium intake on bone mineral density, these studies can be misleading because the effects are small and temporary; once calcium supplementation is stopped, bone mineral density typically returns to that of the placebo group.

Calcium and vitamin D supplementation may prevent fracture risk. A meta-analysis of 15 clinical trials with calcium supplementation observed a 23% reduction in vertebral fractures and 14% in non-vertebral fractures (Shea *et al*, 2004). Two meta-analyses of calcium and vitamin D supplementation trials in 45 000 to 64 000 individuals 50 years and older found a 25% reduction in hip fracture risk (Tang *et al*, 2007), a 12% reduction of all fractures and 24% reduction of all fractures in those with high compliance to the treatment (Boonen *et al*, 2007). The WHI trial found a significant 29% decrease in the risk of hip fracture with 1000 mg day^{-1} of calcium and 400 IU day^{-1} of vitamin D supplementation among participants with good compliance to the treatment (Jackson *et al*, 2006). One of the difficulties in evaluating the effects of calcium on fracture risk is that in many studies it has been combined with vitamin D. In a meta-analysis of intervention trials using vitamin D supplementation, doses less than 700 IU day^{-1} had no effect on risk of fractures, but higher doses of 700–800 IU day^{-1} significantly reduced the risk of hip fractures by 26%, and reduced non-vertebral fractures by 23% (Bischoff-Ferrari *et al*, 2005). However, a recent meta-analysis found no relation between calcium intake and risk of hip fractures in prospective cohort studies, and no significant reduction in the risk of non-vertebral fractures in randomized trial of calcium supplements that did not include vitamin D, with a possible increase in risk (Bischoff-Ferrari *et al*, 2007). Thus, most people appear to be consuming sufficient calcium for bone health, and increases in vitamin D are likely to reduce risk of fractures, either by effects on bone health or reductions of falls.

Calcium intake has been hypothesized to reduce the risk of cardiovascular conditions, possibly by decreases in blood pressure. In the Nurses' Health Study, low calcium intake was associated with greater risk of ischemic stroke in middle-aged American women (Iso

et al, 1999); intake above 600 mg day^{-1} did not appear to further reduce the risk. In the same population, calcium intake was not related to the risk of CHD (Al-Delaimy *et al*, 2003). Several meta-analyses of clinical trials suggest that calcium supplementation may reduce the risk for high blood pressure (Allender *et al*, 1996; Griffith *et al*, 1999; Hajjar *et al*, 2003; Dickinson *et al*, 2006; van Mierlo *et al*, 2006), but the effect appears to be small and may only benefit those with low dietary intakes. Although the evidence has been inconsistent, in some circumstances, higher calcium intake may reduce the risk of pre-eclampsia (Hofmeyr *et al*, 2006).

Vitamin D may also be related to systemic and local inflammation. A meta-analysis of 19 cross-sectional, 13 case–control and 12 prospective studies suggests that low serum 25-hydroxyvitamin D [25(OH)D] levels or vitamin D intake is associated with glucose intolerance, β cell function and insulin resistance, and with the risk of diabetes and metabolic syndrome in individuals from different populations and age groups (Pittas *et al*, 2007). The Nurses' Health Study also found that a high intake of calcium and vitamin D was associated with a reduce risk of type 2 diabetes compared with a low intake (Pittas *et al*, 2006). Furthermore, vitamin D and calcium deficiencies result in bone loss and increased inflammation, which are both components of periodontal disease (Hildebolt, 2005). Vitamin D also has immune-modulatory functions by which it may reduce periodontitis susceptibility (Dietrich *et al*, 2005). Serum levels of 25(OH)D have been associated with gingivitis (Dietrich *et al*, 2005) and periodontal disease (Dietrich *et al*, 2004). Low dietary calcium and dairy products intake are associated with increased levels of periodontal disease (Nishida *et al*, 2000a; Al-Zahrani, 2006). A clinical trial of calcium and vitamin D supplementation showed increased tooth retention after 3 years in the elderly people (Krall *et al*, 2001).

Few studies have assessed the protective effects of foods on caries. Recent studies have suggested that milk and cheese are related to reduced risk of caries; however, this is still not well established. Postulated mechanisms may involve buffering of acids, salivary stimulation, reduction of bacterial adhesion, reduction of enamel demineralization, and/or promotion of remineralization by casein and ionizable calcium and phosphorous (Moynihan *et al*, 1999; Kashket and DePaola, 2002).

Calcium and vitamin D intake may also be related to lower colon cancer risk. In a pooled analysis of 10 cohort studies, with more than 500 000 subjects followed for up to 16 years, those with the highest intake of milk and calcium had significantly reduced risk of colon cancer (Cho *et al*, 2004). This effect was stronger for calcium from foods compared with calcium from supplements (Hartman *et al*, 2005). Evidence from large cohort trials (the Cancer Prevention Study II Nutrition Cohort and the Multiethnic Cohort Study) also favors a protective effect among men (McCullough *et al*, 2003; Park *et al*, 2007) but not among women (Lin *et al*, 2005; Wactawski-Wende *et al*, 2006). Meta-analyses of clinical trials also indicate that calcium supplementation may prevent colorectal adenomatous polyps (Weingarten *et al*, 2004) and recurrent colorectal adenomas (Shaukat *et al*, 2005). In addition, higher blood levels of vitamin D (25-OH D) have been consistently associated with reduced risk of colorectal cancer and higher intakes of vitamin D have also been related to lower risk (Gorham *et al*, 2005; Wei *et al*, 2008). Some evidences suggest that higher vitamin D levels may reduce the risk of breast cancer (Autier and Gandini, 2007; Garland *et al*, 2007; Gissel *et al*, 2008) and decrease total mortality rates (Autier and Gandini, 2007).

On the other hand, calcium and dairy product intake may be related to higher risk of prostate cancer. Meta-analyses of prospective studies indicate that high consumption of milk and dairy products (about >3 servings per day) increases the risk of prostate cancer (Gao *et al*, 2005; Qin *et al*, 2007; WCRF, 2007). A large prospective study found >2.75 servings per day of dairy products, particularly low-fat types and >2000 mg day^{-1} of calcium were modestly associated with increased risks only for non-aggressive prostate cancer (Ahn *et al*, 2007), but in most studies the associations have been primarily with metastatic or fatal prostate cancer. Although consumption of dairy products has been associated with the risk of ovarian cancer in some studies, in a large pooled analysis, the association with total dairy products and calcium intake was not significantly associated with the risk of this cancer (Genkinger *et al*, 2006). However, when expressed as lactose intake, a modest increase in risk was seen at levels equivalent to about three glasses of milk per day. Milk or dairy product consumption has not been associated with increased risk of breast cancer (Missmer *et al*, 2002; Shin *et al*, 2002; McCullough *et al*, 2005).

Impact of tooth loss on nutrition

Several cross-sectional studies have shown associations between tooth loss and compromised diet (Joshipura *et al*, 1996; Krall *et al*, 1998; Walls and Steele, 2004). There are limited longitudinal studies investigating whether tooth loss leads to dietary changes. The association between self-reported tooth loss and concomitant dietary changes was investigated over a period of 8 years among 31 813 male US health professionals. Men who lost five or more teeth during the follow-up had significant reduction in intake of dietary fiber, whole fruit, increase in dietary cholesterol, and polyunsaturated fat than those who did not lose teeth (Hung *et al*, 2003). Subsequent to incident tooth loss, results from the Nurses' Health Study showed detrimental dietary changes over a 2-year period with a tendency for women who lost teeth to avoid hard foods such as raw carrot, fresh apple or pear (Hung *et al*, 2005). However, these differences were relatively small and their significance with respect to chronic disease risks uncertain (Hung *et al*, 2005). Nevertheless, a small impact on several foods and nutrients could still contribute to a modest overall impact on health.

Guidelines for nutrition

To maintain and promote good health, individuals should consume a variety of healthy foods as described below.

Folic acid
Women in the reproductive age should be taking multiple vitamins that include folic acid if there is any possibility that they might become pregnant. Folic acid has been shown to reduce the risk of birth defects if taken before or during the first few weeks of pregnancy.

Sugar and beverages
Pregnant women and mothers of infants should be given advice on preventing baby bottle tooth decay. They should be discouraged from giving their infants a bottle containing beverages with sugar. Milk should be consumed without sugar. It is extremely important for the prevention of baby bottle tooth decay to not allow infants to continue keeping bottles containing milk or other beverages in the mouth when sleeping, especially if these beverages contain added sugar.

Guidelines to reduce the exposure of children to sugar include avoidance of sodas, 'fruit drinks' or other high sugar beverages, limiting the consumption of fruit juice to one small glass (6 oz) per day, and avoiding sugar containing cough drops, chewing gum and snacks such as candy. Furthermore, good dental care should include appropriate use of fluorides, access to preventive and restorative dental care, limiting cariogenic foods during mealtimes, and rapidly clearing cariogenic foods from the child's oral cavity by tooth brushing.

Fruits and vegetables
Fruits and vegetables provide a variety of micronutrients such as vitamins A, K, C, folate, potassium, magnesium, calcium, iron and fiber. Therefore, individuals should consume a wide variety of these on each meal. The US Dietary Guidelines recommend 4½ cups (nine servings) of fruits and vegetables (not counting starchy vegetables such as potato) for the reference 2000 calorie level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005). This level of intake may be challenging for many people; however, it is important to reassure individuals that even increases in one or two servings a day can have important benefits (Hung *et al*, 2004). Consumption of dark green, yellow and red vegetables should be emphasized to receive the health benefits described in the previous sections.

Whole grains
Whole grains provide plenty of fiber as wells as micronutrients such as vitamin E, folate, some B vitamins, magnesium, copper, selenium and proteins. To increase the consumption of whole grains, individuals should replace white rice, bread and pasta with brown rice and whole grain products, as well as choose whole grain or high fiber cereals for breakfast. This has a double benefit because refined starches have adverse metabolic effects and increase the risks of obesity, diabetes and heart disease, whereas whole grains have positive health benefits. The Dietary Reference Intake in the US for fiber is 25 g in women and 38 g in men (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005). To obtain the recommended amount of fiber, individuals should consume whole grain products in most meals.

Nuts
Nuts provide plenty of mono- and poly-unsaturated fatty acids, vitamin E, magnesium and copper, and protein. Individuals should include nuts in their daily diet. Although nuts are often considered as a snack and they are a healthy snack, they can also be considered as a protein source and replace meat in a mixed dish or with a salad. It is recommended that individuals consume 1–2 oz nuts per day (42 g day^{-1}).

Fish
Fish and other seafood are rich sources of omega 3 fatty acids. Individuals should consume a variety of fish two or more times a week. Part of the benefit of fish can be due to replacement of foods high in saturated fat, such as red meats. Pregnant women should avoid the consumption of big fish, such as shark, swordfish, king mackerel or tilefish and tuna due to their high mercury content. Salmon and small fish, such as catfish, snapper, tilapia, sardines and others, are generally safe during pregnancy because they accumulate less mercury.

Unsaturated oils
Some fats are good. Vegetable oils are rich in mono- and poly-unsaturated fatty acids, vitamins A, E and K. Double benefits are achieved by replacing butter and other animal fats with vegetable oils, such as canola, soybean olive, corn and sunflower for cooking, baking and for salads. Although margarines were high in *trans* fat, at this time, almost all margarines in the US contain zero grams of *trans* fat; although these usually have slightly more saturated fat than liquid oils, they are substantially superior to butter in their fatty acid composition. Until recently, there were concerns about fried foods as fats used for deep frying commercially were universally high in *trans* fats, but most restaurants are now using trans free oils that are high in unsaturated fats. There is no evidence that fried foods are inherently harmful; their health effects are related to the type of fat and their potential contribution to excessive caloric intake.

Low-fat dairy products
Dairy products are rich in calcium, phosphorus, potassium, vitamins A and D, some B vitamins and protein. However, dairy products also provide saturated fat. Therefore, individuals should substitute whole-fat products with lower fat products. The US Dietary Guidelines recommend three daily servings of low fat dairy products to achieve calcium requirements for preventing bone loss later in life (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005). However, as the evidence suggests both benefits

and harmful effects of dairy products intake on health, limiting dairy products to about two servings a day seems desirable. Other foods, such as cruciferous (brassica) vegetables (broccoli, spinach, cabbage, cauliflower, brussels sprouts, kale, collard greens, bok choi and kohlrabi) and tofu also provide absorbable calcium (2–5 servings of these products could substitute one serving of dairy product), as well as supplements. As the overall evidence suggests that vitamin D supplementation prevents bone loss, falls, fractures and other chronic diseases, most individuals would probably benefit by using a vitamin D supplement daily. The optimal dose is being actively investigated and is not yet established; 1000 IU day^{-1} provides benefits, but optimal intakes may be several times this amount.

The revised USDA Pyramid 2005 recommends that individuals consume low amounts of fat and eat large amounts of carbohydrate-rich foods, but pays insufficient attention to the adverse effects of refined starches, and gives inadequate attention to the benefits of healthier oils. A food guide pyramid should encourage the consumption of healthy fats and whole grain foods, minimizing the refined carbohydrates, sugar, butter, and red meat.

Key recommendations for preventing obesity

As stated above, obesity is a major growing problem with many health implications. Some key recommendations include:

1. pay attention to portion sizes and total caloric intake;
2. be physically active;
3. consume whole grain, high fiber carbohydrates as opposed to rapidly absorbed carbohydrates;
4. consume more fruits and vegetables;
5. reduce sugar consumption including beverages such as regular carbonated beverages and fruit drinks with added sugar;
6. limit fast foods.

Role of dentists in influencing nutrition

Dentists should play a more active role in preventing and controlling dental caries and periodontal diseases, which are the major indicators for tooth loss. Advice on good dietary habits that help maintain both oral and general health could be included as part of routine preventive care. The importance of retaining teeth and the consequences of tooth loss should be stressed to patients before problems develop, and maintaining good nutrition should be emphasized before extractions are preformed. When dentists recommend extractions, they should inform the patient of the possible consequences of tooth loss on chewing, nutrition, and subsequently on systemic health (Joshipura, 2005). The visit during which the extractions are performed is an additional opportunity to inform the patient about the value of maintaining a healthy diet, for both dental and systemic health. If major chronic diseases are already present, referral to a dietitian may be needed. The need for a good prosthesis should be emphasized to enable patients to chew more efficiently after tooth loss. Follow-up visits for patients with new prosthesis should be scheduled to check its fit and comfort levels, but specifically to inquire about any difficulty encountered while eating when using the prosthesis, and to address this as soon as possible by adjusting the dentures. Even with a good prosthesis, it may be necessary to adjust the preparation of some foods by having hard-to-chew items processed in a way that makes them easier to eat with a compromised dentition, while retaining their nutritional value.

Conclusions

There is strong evidence that a diet rich in fruits, vegetables, whole grains, nuts, fish and unsaturated fats together with regular physical activity contributes greatly to overall health, including dental health. The appropriate role of dairy products in a healthy diet remains unsettled as both beneficial and harmful effects have been observed. At this point, prudence suggests an emphasis on low fat products and limiting intake to about two servings per day. Overweight and obesity is a huge and growing problem; low fat diets have little benefit, but elimination of sugar-sweetened beverages, attention to overall caloric intake, and regular physical activity will contribute to weight control.

Author contributions

All authors drafted and revised this review.

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