IN BRIEF

- This paper summarises a broad range of practice-relevant information on diet and dental health.
- It provides a reference guide for giving dietary advice to patients
  The main advice to give patients is:
  - Limit the frequency of consumption of sugary food and drinks.
  - Eat more vegetables and fruit and starchy staple foods such as bread, potatoes unsweetened breakfast cereals and grains.
  - Drink milk and water rather than sugary acidic soft drinks.

Dietary advice in dental practice

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This paper aims to provide dental health professionals with practical advice to pass on to patients about diet and dental health. Sugars are the most important dietary factor contributing to dental caries. Different foods carry different dental health risks; those containing non-milk, extrinsic sugars are potentially the most damaging. In the UK, sugared soft drinks and confectionery contribute approximately 50% to total intake of non-milk extrinsic sugars. Patients should be encouraged to reduce the frequency of intake of sugary foods. Intake of acidic foods and drinks contributes to dental erosion and consumption of such foods should also be limited. Dietary advice to dental patients should be positive and personalized if possible and can be in line with dietary recommendations for general health. These are to increase the consumption of starchy staple foods (eg bread, potatoes and unsweetened cereals), vegetables and fruit and to reduce the consumption of sugary and fatty foods.

In 1989, The Department of Health Committee on Medical Aspects of Food Policy (COMA), in the report *Dietary Sugars and Human Disease*,[1] recommended that 'Dental practitioners should give dietary advice, including reduction of non-milk extrinsic sugar consumption as an important part of their health education to patients...'. Since this time, dental erosion has been recognised as an issue of growing concern and has been studied specifically in a recent oral health survey.[2] Additional dietary advice is required to help patients reduce their risk of developing dental erosion. Despite these important messages, many dentists do not give dietary advice and when given, it is often *ad hoc*, usually as a single statement with little interaction with the patient.[3] The reticence to provide dietary advice may be due to time, physical space and financial constraints. It may also be due to a lack of clear, consistent information on what advice should actually be given regarding sugary and acidic food and drinks, and their mode and frequency of consumption. The objective of this paper is to provide dental health professionals with practical advice to pass on to patients about diet and dental health, including guidance on the prevention of dental caries and erosion.

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DENTAL CARIES

The prevalence of dental caries in the UK remains unacceptably high. A total of 53% of 4–18-year-olds have dental decay,[2] and the prevalence of decay increases with age from 37% in 4–6-year-olds to 67% in 15–18-year-olds. There is also evidence that the prevalence of caries in preschool children may be increasing;[4] 17% of this age group have decayed teeth, and prevalence increases with age to 30% in 3.5–4.5-year-olds.[5]

The occurrence of dental caries is influenced by the composition of the teeth, the type and quantity of oral bacteria, composition and flow rate of saliva, the presence of dietary sugars, the residence time of sugars in the mouth, and the presence or absence of fluoride.[6] There is a wealth of evidence to show that sugars are undoubtedly the most important dietary factor in the aetiology of dental caries.[7] Foods and drinks that contribute to dietary sugars intake are listed in Table 1. Fluoride has a marked effect on caries reduction but it has not eliminated caries. This is because although fluoride increases the resistance to dental caries, it does not get rid of the

Table 1 Potentially cariogenic foods and drinks

- Sugar and chocolate confectionery
- Cakes and biscuits
- Buns, pastries, fruit pies
- Sponge puddings and other puddings
- Table sugar
- Sugared breakfast cereals
- Jams, preserves, honey
- Ice cream
- Fruit in syrup
- Fresh fruit juices
- Sugared soft drinks
- Sugared, milk-based beverages
- Sugar-containing alcoholic beverages

cause of dental caries – dietary sugars. Where there is adequate exposure to fluoride a further reduction in caries will not occur unless there is a reduction in sugars intake. It must also be noted that not all patients have fluoridated water supplies and may not use fluoride toothpaste regularly. A recent systematic review of the evidence for an association between sugar intake and dental caries in modern society concluded that limiting sugar intake is still important in the prevention of caries.[8]

FREQUENCY OR AMOUNT OF SUGARS

There is evidence to show that both the frequency[9-11] and the amount[12-14] of sugars consumed are associated with dental caries and the evidence for one is not stronger than the other. In the UK and in many Westernised countries, it is public health policy to reduce the amount of sugars consumed,[15,16] but at the level of the individual it is more practical to advise to limit the frequency of intake, as this is easier to quantify. This should not be interpreted to mean that reducing the frequency of sugars is more important than reducing the amount. As the frequency and amount of sugar consumed are closely associated, efforts to reduce frequency should also result in a reduction in the quantity consumed.[17-20]

CLASSIFICATION OF SUGARS FOR DENTAL HEALTH PURPOSES

In 1989, COMA classified sugars for dental health purposes, distinguishing between sugars naturally integrated into the cellular structure of the food (intrinsic sugars) and those present in a free form or added to food (extrinsic sugars).[1] Extrinsic sugars are more readily available for metabolism by oral bacteria than intrinsic sugars and are, therefore, potentially more cariogenic.[1] Due to the lower cariogenicity of lactose[18] and the cariostatic nature of milk,[21] sugars naturally present in milk and milk products are classified as 'milk sugars' and are distinguished from other free sugars or 'non-milk extrinsic sugars' (NMES). The sugars that are potentially damaging to dental health are the NMES and include all added sugars, sugars in fresh fruit juices, honey and syrups. The dietary reference value (DRV) for NMES is a maximum of 60 g/day, which equates to approximately 10% of daily energy intake.[15]

CURRENT LEVELS OF SUGARS INTAKE AND THE MAIN DIETARY SOURCES

The National Diet and Nutrition Survey of young people aged 4–18 years provides up-to-date, comprehensive data on the sugars component of the diets of children.[22] Overall, NMES intake was 85 g/day (SD 38.7 g/day) in boys and 69 g/day (SD 29.0 g/day) in girls, which equates to approximately 17% of daily energy intake. These values are above the DRV. Figure 1 shows the percentage contribution of different foods to total NMES intake. The main source of sugars in the diets of both boys and girls is sugared, non-low-calorie soft drinks, with confectionery being the second largest source. Together, soft drinks (including fresh fruit juice which is high in NMEs) and confectionery contributed to more than 50% of NMES intake. Both of these food categories tend to be consumed between meals, which in addition to being of particular concern for dental health, may also be associated with obesity.[23]

STARCHY STAPLE FOODS

Dietary starch is heterogeneous – it is naturally present in a number of different food types, refined to varying degrees in different types of manufactured foods and is sometimes cooked and sometimes consumed raw. All of these factors need to be considered when assessing the cariogenicity of starch-containing foods.

Raw starch is of low cariogenicity. With the exception of raw vegetables, however, most starch is cooked or refined for consumption. Cooked and highly refined starch does have the potential to cause dental decay,[24] particularly if it is retained in the mouth long enough for amylase digestion to occur. Animal experiments have also shown that combinations of cooked starch and sucrose (eg biscuits and cakes) cause more caries than sucrose alone.[25] Therefore, baked and processed sugar-containing starchy foods, such as cakes, biscuits and sugared breakfast cereals, may be of particular concern. Current dietary guidelines encourage the consumption of starch-rich staple foods (such as bread, potatoes, unsweetened breakfast cereals and grains), and vegetables that naturally contain starch. There is no epidemiological evidence to show that these staple starchy foods and vegetables are harmful to teeth.[18,26,27]

FRUIT AND FRUIT SUGARS

Current dietary guidelines recommend at least five portions of fruit and vegetables per day. Fruit provides essential nutrients and its consumption is negatively associated with several chronic diseases including cardiovascular disease and cancer.[28,29] Fruit does contain sugars (fructose, sucrose and glucose) and plaque pH studies and incubation studies have shown that fruit is acidogenic.[30,31] However, data from epidemiological studies largely show that fruit is non-cariogenic.[7] The 1989 COMA report *Dietary Sugars and Human Disease*[1] concluded that 'fresh fruits as eaten by humans, also appear to be of low cariogenicity (report paragraph 6.7). Furthermore, this report stated that NMES in the

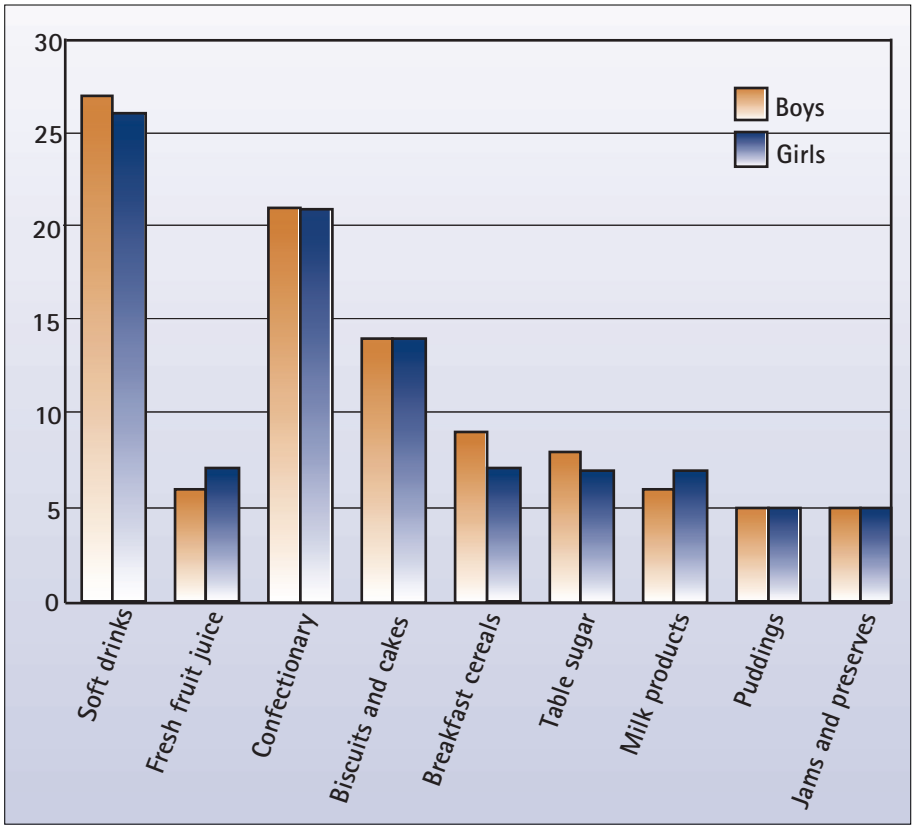

Figure 1 Sources of non-milk extrinsic sugars (NMES) percent contribution to total intake in boys and girls. Data from the National Diet and Nutrition survy of young people aged 4–18 years (n=845)[22]

diet should be replaced with fresh fruit, vegetables and starchy foods (report paragraph 14.3.3).

Fresh unsweetened fruit juice also contains NMES because the juicing process releases the fructose, sucrose and glucose from the whole fruit. The NMES content of unsweetened juice may amount to as much as a standard soft drink, so it is potentially cariogenic.[32,33]

Dried fruit is likely to be more cariogenic than fresh fruit,[34] as the drying process degrades the cellular structure of the fruit, releasing some intrinsic sugars into NMES. Dried fruit also has a tendency to adhere to the teeth, giving it a prolonged oral retention time and compounding its cariogenicity. As consumption of dried fruit is low, however, there are no epidemiological data linking its consumption to dental caries.

MILK SUGARS

Cow's milk is non-cariogenic, as the sugar present is lactose – the least cariogenic of all mono- and disaccharides.[18] Milk also contains factors (calcium phosphate and casein) that protect against demineralisation of enamel.[21] Evidence from animal experiments strongly suggests that milk may be anti-cariogenic. Bowen showed that milk caused virtually no dental caries in rats from which the salivary glands have been removed (and which were therefore caries-prone).[35] Cheese and yoghurt without added sugars may, therefore, be considered safe for teeth. Milk products with added sugars cannot, however, be considered as protective against decay, and do make a sizeable contribution to NMES intake in the UK (approximately 7%, Figure 1).[22]

'HIDDEN SUGARS' AND FOOD LABELLING

Many foods carry nutrition labels that show the total sugars content of the product in g/100 g. Total sugars includes all mono and disaccharides but excludes oligosaccharides such as fructo-oligosaccharides (found for example in some 'sugar-free' chewable vitamins and yoghurts), maltodextrins (tasteless oligosaccharides that are used to increase the energy content of food without increasing the sweetness and are also used as anti-caking agents in dried packet foods) and glucose syrup. Information from incubation, plaque pH and animal studies indicate that these types of oligosaccharides are potentially cariogenic,[36-38] though no clinical trials have been conducted.

The only sweeteners that are safe for teeth are the sugar alcohols (eg sorbitol and mannitol), Lycasin (hydrogenated glucose syrup) and isomalt – and the 'intense' sweeteners, such as aspartame and acesulphame K (Table 2). In fact, there is some evidence suggesting that the sugar alcohol, xylitol, may actually have a have a specific anticariogenic effect.[39,40] However, the laxative effect of the sugar alcohol sweeteners will limit their use in the diet.

Table 2 Non-cariogenic, non-sugar sweeteners that are permitted for use in the UK (trade names are given in brackets)

Bulk sweeteners	Intense sweeteners
Sorbitol	Saccharin
Mannitol	Aspartame (NutraSweet, Canderel)
Xylitol	Acesulfame K (Sunett)
Maltitol	Thaumatin
Lactitol	
Isomalt (Palatinit)	
Hydrogenated glucose syrup (Lycasin)	

The 1989 COMA report[1] concluded that 'non-sugar bulk and intense sweeteners are non-cariogenic or virtually so' and that 'substitution of sugars with alternative sweeteners could substantially reduce caries development, the greatest gain would be expected to occur if they were used to replace sugars in foods ingested frequently, such as sweet snacks, drinks and liquid medicines'. This statement refers to the sweeteners listed in Table 2 and not to glucose polymers and synthetic oligosaccharides. Both the 1989 COMA report[1] and the British Nutrition Foundation Oral Health Task Force Report[6] recommended that manufacturers increase production of affordable sugar-free or low-sugar snacks. Some people are concerned about the general safety of non-sugar sweeteners. However, the use of sweeteners is tightly regulated and a sweetener may only be used once the safety had been assessed by The Committee of Toxicology who advises the Food Standards Agency on the safety of food chemicals. A detailed discussion on the safety of non-sugars sweeteners is outside the scope of this paper – the reader is referred to www.foodstandards.gov.uk

DIETARY GUIDELINES FOR GENERAL HEALTH

For the purpose of nutrition health education, the nutritional targets set out by the Department of Health[15] are translated into food terms in the Health Education Authority document, *The Balance of Good Health*.[41] This outlines a National Food Guide (NFG) which recommends that, in terms of volume, one third of the diet should be provided by bread, other cereals and potatoes, choosing whole-grain varieties wherever possible. One third of the diet should be provided as fruit and vegetables, choosing a wide variety including fresh, frozen and canned. A glass of fruit juice a day may also contribute to this. It recommends avoiding added sugar or syrupy dressings to fruit. The NFG recommends eating moderate amounts of milk and dairy foods and of meat, fish and alternatives, choosing lower fat versions wherever possible. It is recommended to eat sparingly such fatty and sugary foods as spreading fats, oils, dressings, cream, confectionery, sugar, crisps, biscuits, cakes, pastries, puddings, ice-cream, rich sauces and fatty gravies. Subsequent health reports have reiterated and added to these recommendations. For example it is now recommended that daily fruit and vegetable consumption should be at least 400 g/day or five portions and that two portions of fish should be consumed weekly, one of which should be oily.[28] These general guidelines apply to the population aged between 5 and 65 years. Specific needs of older adults were addressed in the COMA report *The Nutrition of Elderly People*[42] and the diets of infants and young children in the COMA report *Weaning and the Weaning Diet*.[43]

DIETARY RECOMMENDATIONS FOR THE PREVENTION AND MANAGEMENT OF DENTAL CARIES

From a dietary point of view, the best advice for reducing caries risk is to reduce the frequency of consumption of sugars-containing food and drinks and to limit their consumption to mealtimes only. It is also advisable to avoid sugars-containing food and drinks close to bedtime (within one hour),[44] as salivary flow is low and its buffering capacity is reduced at night.[45,46] A common eating pattern, however, is to eat little and often – a pattern sometimes referred to as 'grazing'. In this case, suggesting that patients should limit food consumption to three times a day may be totally unrealistic and impractical. If between-meal snacking is unavoidable, it is important to recommend food and drinks that carry a lower caries risk or may help to prevent caries, such as the items listed in Table 3. Patients should be encouraged to eat foods, such as cheese and chew sugar-free gum after meals to neutralise the acidogenic effects of dietary sugars.[18] Numerous clinical trials have shown that chewing sugar-free gum protects against dental caries.[47] In view of the caries-preventive effect of chewing sugar-free gum it is now accredited by the BDA as helping to prevent dental caries. As little as 5 g of hard cheese has been shown to be effective against dental caries in children;[48] this quantity would make an insignificant contribution to fat intake.

Parents of infants should be made aware of the dangers of bottle caries,[49] and mothers should be advised not to add any food or drink to a baby's bottle other than formula milk, expressed breast milk, cow's

Table 3 Foods and drinks with low potential for dental caries

Low/no caries risk	Possible anti-cariogenic effect
Bread (sandwiches, toast, crumpets and pitta bread)	Milk
Pasta, rice and starchy staple foods	Cheese
Unsweetened or artificially sweetened yogurt	Peanuts
Low-sugar breakfast cereals (e.g. shredded wheat)	Sugar-free chewing gum
Sugar-free confectionery	Fibrous foods (e.g. raw vegetables)
Fresh fruit (whole and not juices)	Xylitol sweeteners, gum and mints
Water	Tea (unsweetened)
Sugar-free drinks	

milk or water.[43] As soon as possible, infants should be encouraged to use a cup or beaker rather than a bottle and all bottle feeding should cease by one year old.[43] Cow's milk is lower in sugar than formula milk and is higher in the protective factors, calcium and phosphorus. However, no cow's milk should be given before the age of six months due to the risk of allergy and the high solute load. From six months onward, cow's milk may be integrated into the diet but the main source of milk should remain breast milk or formula, both of which are higher in iron. From one year, full fat cow's milk may be given, from two years semi-skimmed milk and from five years fully skimmed milk, if desired.

It has been hypothesised that reducing the amount of sugars consumed would lead to an increase in fat consumption, the so called 'sugar/fat seesaw'.[50] However, the data for this argument comes from cross sectional analysis of the diets of populations and not from study of populations following changes in intakes of sugars or fats. Recent evidence from a repeated cross sectional study of English school children does not support the existence of an inverse relationship between fat and sugars, showing a significant reduction in intake of fat between 1990 and 2000, that was not accompanied by an increase in sugars intake.[51] Other dietary intervention studies have shown simultaneous reductions in intake of added sugars and fat.[52] It must also be emphasised that permitting unlimited sugars consumption may not lead to a reduction in dietary fat.

DENTAL EROSION

Dental erosion is the loss of dental hard tissue by a process that does not involve bacteria. There are a number of causes of erosion of tooth tissue, including acids in foods, intrinsic acids (from vomiting or reflux) or environmental acids.[53] Although acids in the diet are the most commonly cited causes of erosion, it is important to take a careful patient history to identify those patients in whom reflux or vomiting or environmental acids are the main cause of dental erosion. Such patients will require appropriate counselling. Acids in foods include citric, malic, phosphoric, tartaric, acetic and carbonic acids, and the presence of any of these terms on the nutrition label may indicate that the product is potentially erosive. Carbonic acid is the least erosive dietary acid and the consumption of carbonated water has not been implicated in dental erosion.[54,55]

The level of dental erosion in children in the UK is unacceptably high; nearly 10% of preschool children have severe erosion of their upper front teeth,[5] and 65% of 4–6-year-olds and 62% of 15–18-year-olds have erosion to either their primary or permanent teeth.[2] Erosion often co-exists with other forms of tooth wear, such as attrition and abrasion where enamel softened by acid has been worn away by over-zealous tooth-brushing[7,56] or grinding of teeth.

Foods associated with dental erosion are listed in Table 4. The relative importance of these dietary factors varies, for example there is consistent evidence from cross sectional studies, case-control studies and case studies to implicate soft drinks and fruit juices in erosion but much less evidence for an association between whole fresh fruit consumption and erosion. Jarvinen[54] in one case-control study found that consumption of two or more citrus fruits a day was a risk factor for dental erosion but other reports are of individual cases of excess consumption (eg two oranges or apples/ day plus the juice of 10 oranges per day plus 2 kilograms of stewed rhubarb per week.[57] There is also evidence that juices are 3–10 times as erosive as whole fresh fruits.[58] Based on this evidence and the low levels of fruit consumption by children in the UK,[22] increasing fruit and vegetable consumption is unlikely to cause an increase in erosion especially if this recommendation goes hand in hand with a reduction in soft drink consumption.

Table 4 Foods and drinks that have the potential to cause dental erosion

- Soft drinks – carbonated and diluted squashes (including the 'diet' varieties and sports drinks)
- Fresh fruit juices and fruit juice drinks
- Wine, alcopops, cider and perry, spirits consumed with mixers
- Some herbal teas
- Fresh fruit such as citrus fruit and apples (not bananas) if eaten often in large quantities *
- Vinegar, sauces and pickles (large quantities) *
- Acidic sweets e.g. acidic fruit drops
- Chewable aspirin and vitamin C tablets (large quantities) *

* Citrus fruits consumed >2/day have been associated with erosion in one case control study. Other case studies of erosion have been reported in individual patients with unusually high intakes of fruit, pickles and 'medications' such as aspirin and ascorbic acid

Much of the clinical evidence for an association between diet and erosion comes from one-off case reports of unusual eating habits (eg consuming the juice of 18 oranges a day, or excessive intake of chewable ascorbic acid.[56] The large increase in soft drinks consumed over the past few decades[55,56,59] is often postulated to be the cause of dental erosion. By comparison, the increase in intake of whole fresh fruit has been very small.[60,61]

Some herbal teas and many alcoholic beverages are acidic, including wine, alcopops and spirits consumed with mixers.[55,62,63] If these drinks are sipped over a long period of time, this may exacerbate their erosive potential, as the longer the teeth are bathed in acid the longer period of time for erosion to occur.

Epidemiological studies that have investigated the association between dietary factors and dental erosion (eg the NDNS surveys[2,5]) are cross-sectional, observing diet and dental status at a single point in time. Dietary habits tend to change over time, however, and it is the intake of acidic food and drinks taken several years previously that may be responsible for current levels of erosion, making cross-sectional studies of limited value. This is less of a problem with young children whose diets may not have changed radically. The NDNS of preschool children showed a relationship between the consumption of carbonated soft drinks and erosion. The NDNS of young people reported that the age-related increase in levels of dental erosion was greatest in the children with the highest consumption of acidic food and drinks. The survey also showed that soft drinks were the largest contributing source to acidic food and drink consumption.[2]

The NDNS showed that the average daily intake of carbonated, sugared soft drinks was twice as high as milk consumption in girls (152 ml versus 75 ml) and water consumption was only 60 ml/day. By contrast, fruit intake was relatively low. Citrus fruit intake averaged 51 g/week for boys and 65 g/week for girls, and apple and pear intake was 151 g/week for boys and 167 g/week for girls[23] (the average orange weighs 160 g).

DIETARY RECOMMENDATIONS FOR THE PREVENTION AND MANAGEMENT OF DENTAL EROSION

Due to the limited number of clinical studies performed to investigate the association between diet and dental erosion, prevention and treatment (from a dietary perspective) are based on common sense rather than an evidence-based approach.[53] As a preventive measure, all patients should be informed of the types of food and drinks that may cause dental erosion (Table 4). In cases of erosion, a dietary history should be carried out to determine which particular foods are relevant to the individual patient and advice tailored to the patient should be given to reduce their consumption. Patients may also be advised to consume foods and drinks with low/no erosive potential (Table 5) and to take foods that neutralise dietary acids, such as cheese and milk, following acidic foods and drinks. Cheese protects the teeth by stimulating salivary flow and by increasing plaque calcium concentration. This may be achieved with a small amount of cheese (~5g) thus having a negligible contribution to fat intake.[48]

All patients should be advised to keep acidic drinks to mealtimes if possible, to avoid them close to bedtime and to drink them down in one go rather than sip them over a long period. Wherever possible, these acidic drinks should also be low in sugars to minimise dental caries. The best drinks are, therefore, milk and water. However, it is unrealistic to expect children to drink nothing but water and milk. One soft drink, Ribena ToothKind, has been specially developed to help overcome this problem. Ribena ToothKind has an increased pH and added calcium to minimise the dissolution of tooth enamel in the presence of acid. Plaque pH studies and enamel slab experiments both *in vitro* and *in vivo* show Ribena ToothKind to be of low acidogenicity and to be non-erosive.[64-68]

Table 5 Foods and drinks with low/no erosive potential

- Bread (sandwiches, toast, crumpets and pitta bread)
- Pasta, rice and starchy staple foods
- Fibrous foods (eg raw vegetables)
- Low-sugar breakfast cereals (e.g. shredded wheat)
- Sugar-free chocolate and sugar-free chewing gum
- Cheese
- Peanuts
- Milk
- Water
- Tea and coffee (unsweetened)
- Ribena ToothKind

Table 6 Key dietary recommendations to safeguard dental health

- Reduce the frequency and amount of sugary and acidic food and drinks and to try to limit these foods to mealtimes
- When a structured meal plan is not followed, limit the consumption of sugary foods to 3–4 times a day
- Avoid sugary and acidic foods and drinks close to bedtime
- Encourage consumption of foods that do not cause, or are known to protect against, dental decay and erosion
- Recommending consumption of some sugar-free products may help achieve these goals in practice
- Encourage patients to read manufacturers labels and follow recommendations on the dilution of squashes and the use of products
- Encourage mothers not to add any drink or food to a baby's bottle, except formula milk, expressed breast milk, cow's milk or water
- Encourage mothers to provide all drinks (including formula) in a cup or beaker to infants from the age of 6 months and cease bottle-feeding by 1 year

CONCLUSIONS

It is possible to bring about dietary change through health promotion and dietary intervention. Examples of success are provided by the downward trend in the contribution of fat to the UK diet and by the new School Fruit Scheme which are reported to be successful. Dietary advice for dental health should be personal and positive and should be in line with dietary advice for general health (which encourages increased consumption of starchy staple foods, fruit and vegetables and a reduction in the consumption of sugary and fatty foods). Therefore patients may be advised to eat more starchy staple foods and vegetables and whole fruit to replace sugary foods, and to drink more milk and water to replace sugary, acidic soft drinks. Dietary advice for dental health does not, therefore, need to conflict with advice for general health. It is important that health professionals are clear and consistent in the dietary advice that is given to patients.

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