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РОЛЬ ФТОРИДОВ И ПИТАНИЯ В КОММУНАЛЬНЫХ ПРОГРАММАХ ПРОФИЛАКТИКИ СТОМАТОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ

THE ROLE OF FLUORIDES AND NUTRITION IN COMMUNITY PREVENTION PROGRAMS OF DENTAL DISEASES

Учебно-методическое пособие

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Изложены современные взгляды на использование фторидов. Приведена информация о влиянии пищевых продуктов на стоматологическое здоровье и международные рекомендации о питании и проведении санитарно-просветительной работы по этому вопросу.

Предназначено для студентов 5-го курса медицинского факультета иностранных учащихся, обучающихся на английском языке.

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ROLE OF FLUORIDES IN COMMUNITY PREVENTION PROGRAMS

The caries process is a loss of mineral (demineralization) as a result of the pH decrease below the critical. The critical value for enamel dissolution is 5–6, and an average value 5.5 as generally accepted. Remineralization occurs when the pH of plaque rises. The presence of fluoride reduces the critical pH by 0.5 units, thus demonstrating its protective effect.

In the Netherlands, children of Turkish or Moroccan mothers had a higher incidence of caries than did the native Dutch children. Cultural influences diminished as the children grew older. A similar study in children aged 18 mo to 4.5 y was conducted in Great Britain. This project examined the relation between the intake of dietary sugars, toothbrushing frequency, social class, and caries experience in a cross-sectional study. The children were classified into 4 groups according to social class and toothbrushing habits. The associations between diet and caries were examined for biscuits and cakes, candy, chocolate confectionery, soda drinks, and the percentage of energy from added sugars. The strength of the association between social class and caries was 2 times more that between toothbrushing and caries and nearly 3 times more that between consumption of sugars and caries; the associations with other dietary variables were not significant. The association of caries with sugars, both in amount and frequency, was present only for children whose teeth were brushed only once per day. Gibson and Williams concluded that twice daily toothbrushing with fluoride toothpaste may have a greater effect on the reduction in caries in young children than does the restriction of foods sweetened with sugars.

FLUORIDE IN THE PRVENTION OF DENTAL CARIES

Numerous scientific studies gave reason to believe that fluoride is a highly effective means of preventing dental caries, if the concentration of F-ions in the oral fluid is constantly maintained at an optimum level. Methods based on the principle of constant non-intensive fluoride exposure rather than use of therapeutic applications of highly concentrated fluoride preparations are aimed at preventing caries (WHO, STR 846, Geneva, 1994).

There are two strategies of fluorides use (WHO, 1994):

– Constant exposure to low concentration of fluoride.
– Periodic exposure to highly concentrated fluoride.

There is strong evidence that after adding fluoride to drinking water, table salt, or toothpastes, as well as a combination of these methods, the incidence of dental caries steadily declined (P. A. Leous, 1993). Experience of implementing prevention programs shows that for the first time when the population is exposed to fluoride, the reduction in the incidence of tooth decay among young people can be seen in about 2–3 years. Caries in adults is also reduced, but due to the fact that dental caries lesion had already, the intensity of caries reduction will not be as significant as that of children.

Along with a reduction in the incidence of caries, undesirable side effects such as dental fluorosis can occur. However, experience shows that achievement of effective prevention of dental caries by using fluoride is impossible without the development of mild forms of dental fluorosis. It is therefore necessary to find ways to minimize the incidence of tooth decay while minimizing the occurrence of dental fluorosis.

Currently fluorides are widely used around the world for dental caries prevention. According to numerous publications, as well as WHO documents, high effectiveness of this prevention method is established.

WHO experts report in 1994 confirmed the high efficiency and safety of fluorides. It is the basis of the widespread use of fluoride in municipal/community programs. According to the WHO, prevention of tooth decay using fluorides has next characteristic:

EFFICIENCY — High medical efficiency at the community level

ECONOMY — Low cost of prevention programs

ENVIRONMENT — Safe for the population and staff/personnel, do not lead to environmental pollution.

METHODS OF FLUORIDES USE

The action of fluoride is manifested in different ways. Fluoride from the saliva accelerates remineralization of early enamel lesions. In addition, fluorides delay glycolysis when cariogenic bacteria produce acid. High concentrations of fluorides have bactericidal activity against cariogenic bacteria. Consumption of fluoride during formation of teeth makes the enamel more resistant to acid dissolution.

The mechanism of fluoride action:

– acceleration of remineralization;
– slowing glycolysis;
– bactericidal effect;
– increasing the resistance of enamel.

Methods of fluorides use can be divided into 2 groups: local/topical/exogenous and systemic/endogenous fluoridation.

Among the methods of systemic fluoridation can be distinguished: fluoridation of drinking water, fluoridation of table salt, milk fluoridation, fluoride tablets and drops has been gained. Methods of systemic fluorine use for caries prevention are equally effective (50–60 %) in addition to fluoridation of milk.

Fluoride gels, varnishes, toothpaste, and fluoride mouth rinses are the most common means of topical use. Methods of fluorine topical use for caries prevention are equally effective (25–30 %).

Possible methods of fluorine use for dental caries prevention are:

– use of one endogenous method,
– use of several exogenous methods
– combination of one endogenous method and several exogenous.

Fluoridation methods, which have the greatest effectiveness, are systemic methods: fluoridated water, fluoridated salt and fluoride tablets. The most popular endogenous method of fluoride use is fluoridated water, exogenous one is fluoridated toothpaste (fig. 1).

Methods of fluorides' use:

Systemic fluoridation
– drinking water;
– table salt;
– milk;
– the tablet / drop

Local fluoridation
– toothpastes;
– gels;
– varnishes;
– mouthrinses

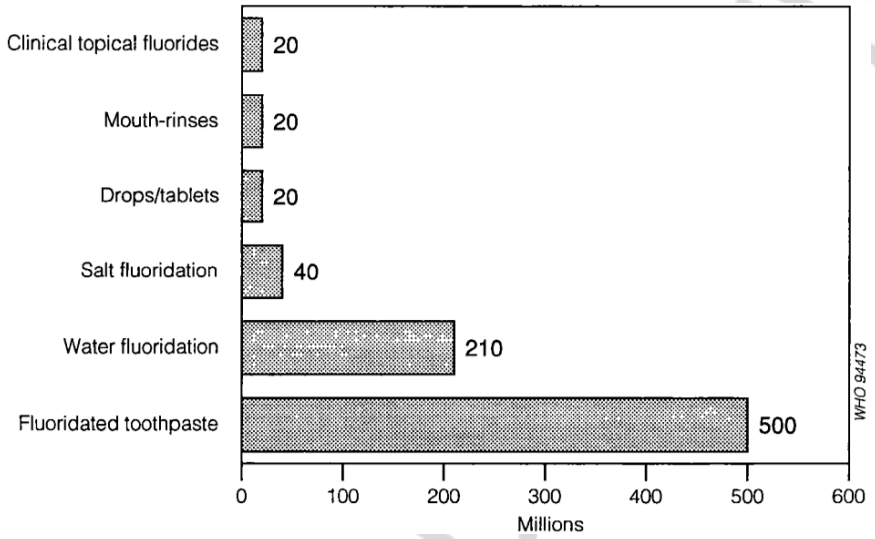


Fig. 1. Tentative estimate of number of people throughout the world using various types of fluoride therapy and preventive measures

FLUORIDE IN DRINKING WATER

Over the past 40–50 years, hundreds of scientific papers were published, confirming the great efficiency of fluoridation of drinking water in the tooth decay prevention, providing it with a caries reduction by 40–50 % from the level in the primary teeth and by 50–60 % in the permanent teeth. According to WHO documents, fluoridation of drinking water at the piped water supply is the most effective method of prevention. The method of drinking water fluoridation is recommended by over 150 different health institutions, including the International Dental Federation (FDI), the International Association of Dental Sciences (IADR) and the World Health Organization (WHO). Programs of drinking water fluoridation were implemented in 39 countries, covering 170 million of people.

Additionally, about 40 million people use natural water containing fluoride at a concentration of 0.7 mg/l or higher. The disadvantage of the method is the necessary piped water supply. It is virtually impossible in many communities, especially in rural areas.

To implement the fluoridation of drinking water, dentists must interact with the authority, engineers, chemists, nutritionists, and internists.

Until 1990 optimum concentration of fluoride in the drinking water was considered 0.7–1.2 mg/L (in tropical countries the dose should be lower in the cold ones — higher). Due to the wide spread of fluoride toothpaste, the emergence of a variety of different beverages and other foods containing fluorine, in 1994 the WHO recommends the following limits for the concentration of artificial fluoridation of drinking water: **0.5 mg/l in the southern and 1.0 mg/l in the northern.**

Provided that a community has a piped water supply, water fluoridation is the most effective method of reaching the whole population, so that all social classes benefit without the need for active participation on the part of individuals.

CONCENTRATION	0.5–1 mg/l
EFFICIENCY	40–50 % primary teeth 50–60 % permanent teeth
USE	39 countries 170 millions of people
DISADVANTAGE	Impossible without piped water supply high cost

Level of dental caries must be sufficiently high, or the risk of an increasing prevalence of caries sufficiently grave, to justify the investment. Provided that a large population is served, the cost per capita can be very small, especially if the initial cost of equipment is spread out over a period of 5–10 years.

The question of possible secondary effects caused by fluorides taken in optimal concentrations throughout life has been the object of thorough medical investigations which have failed to show any impairment of general health.

The use of an ion-specific electrode as an effective method for monitoring fluoride levels in drinking water is generally accepted.

Fluoridated bottled water

Use of fluoridated bottled water (natural or artificially enriched with fluorine) as a method of caries prevention system is connected to a number of production organizational and economic problems. Recently, however, "free market" offers the water in large assortment.

In Belarus, there is a state program of production and sale of fluoridated salt, so dentists can not recommend fluoridated bottled water for caries prevention, as two systemic methods of prevention can not be used simultaneously.

Another aspect of bottled water is its chemical composition. Most of the water, available in the market in the CIS, is highly mineralized, contents of mineral salts is more than 1,500 mg per 1 liter of water. There is no scientific evidence on the benefits of such water for teeth. Should a healthy person use a lot of salt without a doctor's prescription to be even stronger? This problem should be solved by competent experts. Excess of salts in the body can cause a number of diseases.

The partial defluoridation of drinking water

When there is an excess of fluoride in the drinking water, natural methods of defluoridation are used. The methods are divided into centralized and individual. Individual defluoridation of water is performed using granulated bone charcoal.

Industrial methods of defluoridation are used in a number of Middle Eastern countries. This is a complex and costly process of distillation of salt. Then water is enriched in macroelements and fluorine in the required concentrations.

There is now increasing evidence that fluoride is especially effective in controlling root-surface caries. Data from the United States of America showed that root caries prevalence was inversely related to the concentration of fluoride in the drinking-water, and recent data from Ireland confirm these results. In Ireland, the percentage of exposed root surfaces with caries in persons aged 65 years or older was 11.7 in fluoridated areas compared with 18.9 in non-fluoridated areas.

Requirements for application:

– A level of dental caries in the community that is high or moderate, or firm indications that the caries level is increasing.

– Attainment by the country (or area of a country) of a moderate level of economic and technological development.

– Availability of a municipal water supply reaching a large proportion of homes.

– Evidence that people drink water from the municipal supply rather than water from individual wells or rainwater tanks.

– Availability of the equipment needed in a treatment plant or pumping station.

– Availability of a reliable supply of fluoride chemical of acceptable quality.

– Availability of trained workers in the water treatment plant who are able to maintain the system and keep adequate records.

– Availability of sufficient funding for initial installation and running costs.

Conclusions:

1. Community water fluoridation is safe and cost-effective and should be introduced and maintained wherever socially acceptable and feasible.

2. The optimum fluoride concentration will normally be within the range 0.5–1.0 mg/l.

3. The technical operation of water-fluoridation systems should be monitored and recorded regularly.

4. Surveys of dental caries and dental fluorosis should be conducted periodically.

FLUORIDATION OF TABLE SALT

To date, there is relatively little research devoted to the study of medical effectiveness of fluoridated salt. The most convincing evidence of the effectiveness of the method at the community level is obtained in Hungary, Colombia and Switzerland. In Switzerland, the salt is fluoridated for over 40 years and during that time there was a steady reduction in the intensity of dental caries to the DMFT 1.0 and less in 12-year-olds. For example, the experience of Switzerland efficiency of table salt fluoridation equates to drinking water fluoridation.

In Belarus in 1993–1995 caries prevention program was implemented among children in several cities using fluoridated salt food produced by Mozyr salt factory using Swiss technology. Implementation of the program reduced the prevalence and intensity of dental caries in preschool children by 15.5 % and 31 %, respectively (T. N. Terekhova, 1999). Concentration of the F-ion 250 mg/kg has a freely available in fluoridated salt in grocery stores.

There are two levels of implementation: a) **partial**; b) **total.**

Partial implementation of fluoridated salt means use it for household only (domestic salt). Examples of such programs are available in France and Germany. Another type of partial fluoridation is the use of fluoridated salt for baking bread (programs in Costa Rica, Jamaica). According to total implementation fluoridated salt is used for household use and for the preparation of food for the entire population (restaurants and hospitals). Anticarious effect of total dietary salt fluoridation is higher than partial. The maximum effect of fluoridated salt in the prevention of dental caries is achieved when use of the product throughout a person's life (WHO, STR 846, 1994).

Problem associated with the implementation of fluoridated salt is *distribution*. Fluoridated salt should not be used in areas where there are optimal levels of fluoride in drinking water, or other systemic fluoride programs are carried out. In addition, the fluoridation of table salt is a complex technical process, which is necessary to constantly *monitor* at the workplace, including the maintenance of specified concentrations of fluoride in the product.

The economy and safety. In Switzerland, 1 kg of fluoridated salt is in the range of 0.2–0.4 US dollars. Iodized salt and ordinary salt without additives are sold at the same price. In other countries the fluoridated salt prices are higher than usual. In Belarus, fluoridated salt is more expensive than ordinary salt of the same quality and the price.

Fluoridated salt is a safe product. Acute poisoning with fluorine impossible, but the simultaneous use of other fluorine preparations (e.g., tablets) and / or fluoridated drinking water (e.g., bottled water with fluorine) can lead to dental fluorosis.

The concentration of fluorine in the fluoridated salt. The minimum concentration of fluorine, which may cause a reduction in dental caries — 200 mg/kg of salt. The highest safe concentration of fluorine — 350 mg/kg of salt. Medical research of safety for people using these high concentrations held in Hungary.

In calculating the fluorine concentration, one should take into account the daily intake of salt, which varies in different countries in the range of 5–10 g for an adult.

Problems of implementation. In many countries, where there have been attempts to introduce salt fluoridation program, observed failures due to incorrect technology. The main problem was that the predetermined *concentration* of fluoride salt may not be maintained upon prolonged storage or adverse conditions. It is therefore very important to carry out tests on the fluorine content not only in manufacturing, but also in the shops. Also requires monitoring the concentration of fluoride in the body (urine test).

CONCENTRATION	200–350 mg/kg
EFFICIENCY	=water fluoridation
LEVELS OF IMPLEMENTATION	partial total
DISADVANTAGES	complex technology the complexity of in the distribution necessity of F concentration monitoring mandatory monitoring of the level of F in urine
IMPLEMENTATION	Switzerland, France, Costa Rica, Jamaica, Germany, Mexico, Spain, Ukraine (partially), Belarus

Acceptability of the method among the population. The biggest advantage of salt fluoridation to water fluoridation is that the method allows the user to select an individual to use or not use it. In the five countries where fluoridated salt is available, the acceptability of the method to the public is good: in Switzerland (since 1955), France (1986), Costa Rica (1987), Jamaica (1987 g), and in Germany (since 1991). The method has also been successfully implemented in Mexico and Spain. Fluoridated salt is usually available in the Belarusian shops. Department of pediatric dentistry of BSMU conducted research in a number of pre-school institutions to assess the effectiveness of fluoridated salt from Mozyr in the prevention of dental caries. Good results to reduce the incidence of tooth decay was obtained (T. N. Terekhova, 1999). The level of implementation of fluoridated salt food in Belarus is partial. The Republic of Belarus produces fluoridated table salt with the concentration of fluoride 250 mg / kg.

Requirements for application:

– Multiple sources of water posing a serious economic obstacle to water fluoridation.

– Predominance of low-fluoride drinking-water.

– Lack of political will and resources to fluoridate drinking-water.

– Centralized salt production.

WHO recommendations:

1. Salt fluoridation should be considered where water fluoridation is not feasible for technical, financial or sociocultural reasons.

2. The optimum concentration must be determined on the basis of salt intake studies. A concentration of F 200 mg/kg in salt may be regarded as a minimum when several types of salt (domestic and salt for bakeries, restaurants and other large kitchens) are fluoridated, but twice this concentration may be appropriate when only domestic salt is fluoridated.

3. The technical operations of salt fluoridation systems should be monitored and recorded regularly. In addition, the correct concentration and homogeneity should be periodically ascertained in the packages offered to the consumer.

4. The fluoride concentration should appear on all salt packages.

5. Surveys of dental caries and dental fluorosis should be conducted periodically.

MILK FLUORIDATION

Since milk is a product of baby food in many countries over the past 40 years made attempts to introduce fluoridation of milk. There are several clinical studies lasting no more than 5–6 years, which is marked positive effect of milk fluoridation to reduce dental caries (R. W. Stephen et al., 1996).

The biggest problem are product distribution method and the motivation of the population. School programs in Bulgaria, Chile, China, Russia and England were successfully implemented. Concentration of fluorine in milk was 5 mg/l. As part of the prevention program, each child should drink 200 ml of milk a day for about 200 days a year. Investigations of the method effectiveness are continuing in the communal programs. In Belarus, the research justified indication for the fluoridation of milk, as the method of choice for the prevention of dental caries in children's institutions (E. A. Bondarik, 2001), but these proposals have not yet been practically implemented.

CONCENTRATION	5mg/l, 200 ml of milk per day
EFFICIENCY	satisfactory is being studied
LEVELS OF IMPLEMENTATION	pre-school institutions school programms
DISADVANTAGES	the complexity of the distribution insufficient motivation of population
IMPLEMENTATION	Bulgaria, Chile, China, Russia, England

The distribution of fluoridated milk can be more complicated than that of fluoride supplements in the form of tablets or drops. The production of fluoridated milk requires a high degree of motivation and expertise on the part of the dairy industry to ensure adequate controls of the fluoride content. Most of the studies reported have involved distributing the milk at school, and for school schemes to be successful, teachers, parents and auxiliary helpers must be committed to them. While encouraging results in the reduction of dental caries have been achieved with milk fluoridation, further studies are required before the method can be recommended for wide-scale use.

Conclusions:

1. Provided that a community has a well developed milk distribution system, the technical procedures for producing fluoridated milk are straightforward.

2. Encouraging results have been reported with milk fluoridation but more studies are required.

FLUORIDE SUPPLEMENTS (TABLETS AND DROPS)

Over 50 reports on the effectiveness of fluoride tablets or drops have appeared in the literature, although in general the quality of the studies has not been as rigorous as that found in clinical trials of fluoridated toothpastes. Small group

sizes and the absence of randomized designs are common, leading some authorities to question the value of evidence in this field.

The studies consistently concluded that a caries-preventive effect of about 60 % was found in the primary dentition when the initial age was 2 years or younger. With studies on the permanent dentition, the initial age of the subjects and the duration of fluoride tablet intake varied widely. In only four studies were fluoride supplements taken from birth to at least 7 years of age; in these studies the reported caries reductions varied from 39 % to 80 %. It has been shown that sucking a tablet for as long as possible, rather than immediately swallowing it, gives better results in caries prevention.

Implementation. Daily administration of tablets at home requires a very high level of parental motivation, and campaigns to get parents to give their children fluoride supplements have not been successful in many countries, the impact being least in the economically underprivileged sections of a community. Results of home-based trials have to be interpreted with caution, because the attitude to oral health of the mothers who give their children supplements from birth is likely to be more favourable than that of mothers who begin supplementation later, or who form the control group.

There is no logistic problem in the production of fluoride tablets, but there has been considerable discussion as to the optimum dosage of fluoride tablets and drops. Reports on at least 18 different dosage regimens have been published in various countries; all are based on empirical estimates rather than on the results of rigorous scientific studies.

Daily intake drugs at home requires high motivation and organization of parents, so most programs at the community level were short-lived. More successful programs were conducted in schools by using fluoride tablets during the period of at school studyng. But questions of storage of tablets and personnel provision were proved to be difficult.

Economic issues and safety.

Where fluoride supplements are prescribed individually by dentists, the cost of tablets is considerably greater than when they are purchased in bulk and administered in supervised school programmes. In such programmes, the teachers' supervising time is usually not included in the cost of the programme, though it is obvious that supervision is a real and important cost. The actual cost of supervision will vary greatly from one country to another, with different labour charges and cultures.

Determination of the dose. Children up to 3 years old get less than 1 mg of fluoride per day from fluoridated drinking water. Dose of fluoride tablets is calculated based on this and taking into account the actual concentration of fluoride in the drinking water.

All dose of fluorine in the form of tablets enters the body simultaneously. Therefore, risk of fluorosis is greater than when using fluoridated drinking water.

Obviously fluoride tablets should be kept out of reach of young children, and should be packaged in child-proof containers. In some countries the number of

tablets in a container is limited so that there can be no more than 120 mg of sodium fluoride in any one container; this seems a prudent safety precaution.

In some countries, the tablets are given only by prescription, in other countries you can buy them at the pharmacy.

Fluoride tablets (prescribed to pregnant), do not increase the effectiveness of the caries prevention method in programs for children, if after the child's birth he will not get flourine.

Dental Fluorosis. A number of recent studies have established that administration of the tablets may cause dental fluorosis, as well as the swallowing of fluoride toothpaste and fluoride mouth rinses. Teeth are most susceptible in the early period of their maturation. For aesthetically important teeth, such as central and lateral permanent incisors, the greatest risk of dental fluorosis is in age from 18 months to 3 years. These data were the basis for the revision of doses of fluoride.

Doses of fluoride tablets. In the first months of life dose of fluoride tablets should be minimal. However, in practice it is very difficult to control strictly differentiated doses depending on the age of the children.

There has been a general trend towards lowering the fluoride supplement dose, particularly in the early months of life. A further problem is the complexity of most dosage schedules, particularly if there are a number of children of different ages in the family. In addition, fluoride supplements have been found to be ineffective as a public health measure because compliance with the daily regimen is poor and the children who use them are normally from the more oral-health-conscious families. The possibility of an increased risk of dental fluorosis has led some experts in Europe to conclude that:

– fluoride supplements have limited application as a public health measure;

– a dose of 0.5 mg F/day should be prescribed only for individuals at risk, and starting only at the age of 3 years;

– labelling should advise that fluoride supplements should not be used before 3 years of age unless prescribed by a dentist.

In areas with a high incidence of caries recommended doses of fluoride are summarized in table 1.

The doses of fluoride in tablets or drops for children from 6 months up to 16 years with regard to the content of fluoride in the drinking water are recommended by WHO (1994).

Table 1

Current dosage schedule for fluoride supplements in the United Kingdom in relation to fluoride concentration in drinking-water

Fluoride in drinking-water (mg/litre)	**Fluoride dosage (mg/day) by age group**		
	6 months – 2 years	**2–4 years**	**4–16 years**
< 0.3 mg./litre	0.25	0.50	1.00
0.3–0.7 mg/litre	0.00	0.25	0.50
> 0.7 mg/litre	0.00	0.00	0.00

Conclusions:

1. Fluoride supplements have limited application as a public health measure.

2. In areas with medium to low caries prevalence, a conservative prescribing policy should be adopted, and a dose of 0.5 mg F/day prescribed for individuals at risk from the age of 3 years.

3. In areas where there is particular concern about caries in the primary and permanent dentitions, a dosage regimen should be used, starting at 6 months of age, that takes into account the fluoride content of the drinking-water.

4. Prescribed supplements should be issued in child-proof containers. The quantity of sodium fluoride in all the tablets in any one container should not exceed 120 mg.

FLUORIDE GELS

Professional procedures

Solutions and gels with fluorine are used topically. Gel is convenient because it can be applied simultaneously to all the teeth with a special mouth-tray. Professional gel application indicated only for patients at high risk of caries. High medical efficacy of acidified fluorphosphate gel is observed at a concentration 12,300 ppm in preventing dental caries.

Applications of gel indicated not only for children but also for adults who are at *moderate* to *high* risk of caries. The frequency of procedures is at least 2 times a year.

Guidelines for the application of topical gels

Topical fluoride gels should be applied in accordance with the following guidelines, designed to minimize the amount that may be swallowed:

1. Limit the amount of gel placed in each commercially available disposable mouth-tray to no more than 2 ml or 40 % of the tray's capacity.

2. Limit the amount of gel placed in each custom-fitted mouth-tray to 5–10 drops.

3. Sit the patient in an upright position with the head inclined forward.

4. Use suction throughout the gel application procedure 4 min.

5. Instruct the patient to expectorate, or use a saliva ejector for 30 seconds after the gel application.

6. Keep the container out of reach of the patient.

7. Never leave the patient unattended.

Topical fluoride gels are best applied in foam-lined mouth-trays and left in contact with the teeth for 4 minutes. Patients should abstain from eating, rinsing, or drinking for 30 minutes after topical fluoride application. For adults at high risk for caries development, professional application of acidulated phosphate fluoride gels, at 6-month intervals or more frequently, is appropriate. Precautions should be taken to protect porcelain restorations, which may be etched by acidulated solutions and gels, by covering them with petroleum jelly before the gel is applied.

CONCENTRATION	Home use 1 000–5 000 ppm Professional use 12 300 ppm
USE	1 time a week at home 2 times a year at dental office

Self-used gels

In commercially available gels containing a neutral sodium fluoride at a concentration of 5 000 ppm F, acidulated phosphate fluoride (5 000 ppm F) and tin fluoride (1 000 ppm F). In some European countries, fluoride gel for topical application is recommended for pupils from 8 years to use at home once a week. The concentration of fluorine in the gels for home use should be lower than for professional use. At home, you can use an individual mouth-tray or an method of cleansing teeth by gel.

These topical fluoride gels find particular use in two groups of patients who are highly susceptible to caries attack: (a) those undergoing orthodontic treatment, and (b) those with rampant caries from the xerostomia which follows radiation therapy, or prolonged medication, of the head and neck.

POLISHING PASTES

Polishing pastes for professional use contain fluoride concentrations ranging from 4000 to 20 000 ppm. There are no data documenting the caries-preventive efficacy of the annual or semi-annual use of these products. Their primary role is in polishing and they should not be viewed as a prophylactic topical fluoride application unless and until a preventive effect can be demonstrated.

FLUORIDE VARNISHES

Fluoride varnishes, which are usually applied with small brushes or syringes, have been demonstrated as efficacious in caries prevention. They are now widely accepted in Asia and Europe and their use seems to be increasing in the world as a whole. It is recommended that fluoride varnish should be applied at intervals of 3–6 months, predominantly in patients at *high* risk of caries. There is no contraindication to the use of varnishes.

SLOW RELEASE PREPARATIONS WITH FLUORINE

There are two groups of methods:

1) dental materials, which contains fluoride;

2) special intraoral devices.

Encouraging data was obtained about the successful use of glass ionomer cements, of which fluorine flows slowly into enamel and dentin. However further research is needed before recommending these methods at the community level. In addition, we should take into account the economic factor.

Two main approaches have been used for the slow release of fluoride in the mouth: incorporating fluoride into dental materials and using intraoral devices. The incorporation of fluoride in dental materials such as amalgam, dental cements, composites, and pit and fissure sealants does not appear to impart significant clinical anti-caries benefits. The release of fluoride from these materials is short-lived, exhibiting a "burst effect" only, and hence these materials require very frequent reapplication.

The intra-oral devices currently in use are of two types: the copolymer membrane device and the fluoride glass device. The duration of fluoride release by the copolymer membrane device has been between 30 and 180 days, and salivary fluoride levels have been shown to be elevated throughout a 100-day test period. The fluoride glass device releases trace elements over a period of at least one year. Although these techniques may play an important role in the prevention or treatment of dental caries in the future, data from human clinical trials are still lacking.

Medical effectiveness of intra-oral devices, slowly releasing fluorine for several months also needs more convincing evidence in the long-term clinical studies.

FLIORIDE MOUTH RINSING

Over the past several decades, fluoride mouth-rinsing has become one of the most widely used caries-preventive public health methods. Two regimens have been adopted as standard for individual programmes of patient care or for school-based programmes. They are a 0.05 % sodium fluoride rinse (230 ppm F) used daily and a 0.2 % sodium fluoride rinse (900 ppm F) used weekly or fortnightly; these are sometimes referred to as the low potency/high frequency technique and the high potency/low frequency technique, respectively.

We can recommend rinsing the mouth to patients based *upon the individual activity of carious disease regardless of the concentration of fluoride in drinking water.*

For patients with increased caries risk, e.g. those undergoing orthodontic treatment, as well as patients undergoing radiotherapy, fluoride mouth-rinsing is especially beneficial.

School-based fluoride mouth-rinsing programmes are recommended in low-fluoride communities where caries activity *is moderate to high*. In optimally fluoridated communities, school-based fluoride mouth-rinsing programmes are not recommended. There is little or no danger of acute toxic reactions if the products are used in the prescribed or usual quantities. Following correct rinsing, only a minimum amount of fluoride is retained and swallowed. Though the amount retained would not cause fluorosis in a preschool child, it might contribute to the risk of fluorosis depending upon the total amount of fluoride being ingested daily. Therefore, mouth-rinses are **not recommended for children below the age of 6 years.**

As more adults retain more teeth there is a greater risk of increasing coronal and root decay rates. Adults with *moderate* to *high* caries risk can use commercial fluoride mouth-rinses at home. There seems, however, to be an increased tendency to use commercially prepared fluoride rinses which contain an alcohol base. Such preparations are costly and there is no justification, other than flavour and formulation, to use an alcohol base. The daily use and the inadvertent or intentional ingestion of an alcohol-based fluoride rinse are to be strongly discouraged.

When prescribing the above mentioned means of preventing dental caries one should remember that all fluoride preparations for topical application are a potential danger to health, especially children (table 2). Poisoning is possible after ingestion of large fluoride doses. Long-term use of several kinds of fluorides, such as rinsing in combination with food fluoridated salt and fluoridated toothpaste, may lead to chronic intoxication, the first signs of which are manifested in the form of dental fluorosis. Along with the standard precautions (storage out of the reach of children), manufacturers produce products in packages with a safe total dose of fluoride.

Table 2

The fluorine content in formulations for topical use and their relationship with a potentially toxic dose (WHO, 1994)

A drug	**Fluorine concentration (ppm)**	**The amount used**		**The amount of drug (ml), which contains a toxic dose of fluoride for the child's weight**	
		preparation (ml)	**fluorine (mg)**	**10 kg**	**20 kg**
2.75 % solution of NaF (acidulated phosphate fluoride) in the form of a gel	12 300	5	61,5	4	8
0.40 % solution of SnF2 gel	970	1	1,0	50	100
8.0 % solution of SnF2gel	19 400	1	19,4	2,5	5,0
0.05 % NaF rinse solution	230	10	2,3	215	430
0.2 % solution of NaF rinse solution	910	10	9,1	55	110

Daily	0.05 % solution of NaF (230 ppm)
Weekly	0.2 % solution of NaF (900 ppm)
WHO	Not recommended for children under 6 years old Should be stored out of the children reach

FLUORIDE TOOTHPASTE

Investigations into the effectiveness of adding fluoride to toothpaste have been carried out since 1945 and cover a wide range of active ingredients in various abrasive formulations. Fluoride compounds and their combinations that have been

tested for caries-inhibitory properties when incorporated into a toothpaste include sodium fluoride, acidulated phosphate fluoride, stannous fluoride, sodium monofluorophosphate, and amine fluoride. The results of over 100 trials of some of these agents show that brushing with a fluoridated toothpaste will reduce the incidence of dental caries. As experience has accumulated, it has been shown that the cariostatic effect of fluoridated toothpastes in life-long use in entire populations is much greater than that reported from short-term clinical studies of 2–3 years' duration (usually about 25 %).

In many countries, fluoride-containing toothpastes make up more than 95 % of all toothpaste sales, so, provided that a person there brushes his or her teeth at all, the benefits of a topically applied fluoride will be delivered. There is now increasing evidence that the decline in the prevalence of dental caries recorded in most industrialized countries in the past 20 years can be attributed mainly to the widespread use of toothpastes that contain fluoride. Fluoridated toothpastes play an important part in the "personal care products" division of a number of multinational corporations. The highly competitive nature of the market has resulted in continuous efforts to improve flavour and effectiveness and the promotion of toothpastes by the different companies has no doubt contributed to their increased use the world over.

In countries where tooth brushing is widespread among the population, toothpastes may be the most practical means for the local prevention of dental caries. In many countries more than 95 % of the toothpastes are fluoridated. There is more and more evidence that the reduction in the intensity of dental caries, which is observed in the last 20–25 years in many countries, is due to the use of fluoride toothpaste. WHO does not emit special type of a fluoride toothpaste for the prevention of tooth decay. However, it is important that at the level of communal prevention programs were recommended only the paste with effectiveness has been proven in practice in real conditions of the country.

Following the WHO recommendations on the need for clinical testing toothpastes, in the Republic of Belarus in 2000–2004 clinical evaluation of the effectiveness of medical fluoride «Colgate» toothpaste (fluoride ion content of 1050 ppm) among first grade pupils in 5 schools in Minsk was carried out. Brushing teeth was carried out on a daily basis at school after lunch under the supervision of teachers. First-formers from other schools served as a control group (where such a program has not). After 12 months the reduction of caries growth of 41 % by the index of the DMFT and by 37 % by the index DMFS of permanent teeth was set in children who brushed their teeth with «Colgate» paste (fig. 2).

The effectiveness of fluoride toothpaste in caries prevention is 25–30 %. For the adult population of the Republic of Belarus is recommended use of fluoridated toothpastes. In accordance with the international standard toothpaste pH value must be between 5.5–10.5. The basis for the choice of toothpaste is the presence and concentration of fluorine.

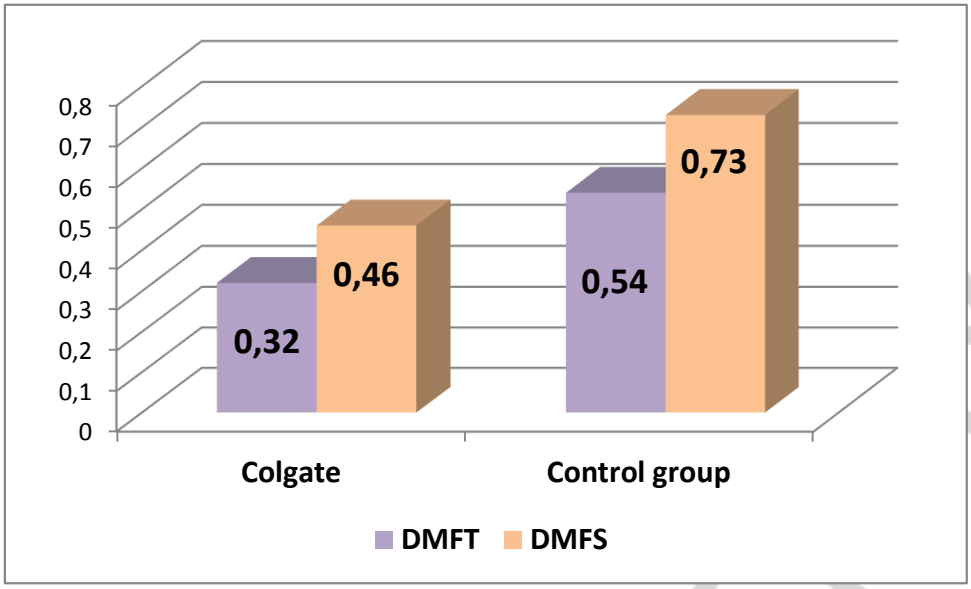


Fig. 2. 12-month increase in caries among first-graders who participated in the prevention program with «Colgate» fluoridated toothpaste

The content of fluorine

In order to comply with the pharmacological principle of using the lowest concentration of an agent to provide maximum benefit without negative side-effects, studies have been undertaken to investigate the dose- response relationship for different fluoride levels in toothpastes up to 2500 ppm. The results suggest that increased fluoride levels give a greater reduction in the incidence of dental caries; they also suggest that the increased benefit is of the order of 6 % for each 500 ppm over 1000 ppm fluoride. The relative effectiveness of pastes yielding less than 500 ppm fluoride has not been established. It is worth noting that in 1977 the European Commission suggested that an upper limit of 1500 ppm fluoride be placed on toothpastes sold over the counter without prescription.

Costs

Despite the widespreading of toothpastes, the most important obstacle to the development of communal programs is their high cost. Therefore, the development of new toothpastes should seek to reduce the cost as in many places, this means may be the only acceptable method of prevention. New toothpaste formulations with enhanced caries-preventive effect should be critically evaluated in terms of costs and added benefits. This is especially important if the cost of a new formulation is greater than that of currently available tooth pastes.

In addition, since the use of fluoridated toothpastes is a public health measure, it would be in the ultimate interest of countries to exempt them from the duties and taxation applied to cosmetics.

Fluoride toothpaste for children

Recent evidence suggests that in industrialized countries many children begin to use a fluoride toothpaste regularly from a young age, in many instances before the age of 1 year, when there is a greater likelihood of their ingesting some of the toothpaste used at each brushing. Studies have shown that the use of a fluoride toothpaste from an early age is associated with higher levels of very mild fluo-

rosis, and this tends to support the view that infants and young children inadvertently swallow a considerable proportion of the toothpaste they use. Because the fluorosis recorded in these studies was confined to the very mild grades and was not aesthetically compromising, the use of fluoride toothpastes should continue to be promoted in communities, whether or not they are served with fluoridated water or salt. In some countries special low- concentration fluoridated toothpastes for young children are being marketed, even though the caries-preventive efficacy of these products has not been established. However, the production of candy-like flavours and toothpastes containing fluoride at 1500 ppm or more should not be encouraged for use by children, as they may lead to an excessive ingestion of fluoride.

At the same time a number of companies are trying to create a special toothpaste for children with a low concentration of fluorine (less than 500 ppm F). But it is not justified from the point of view of the ineffectiveness. WHO recommendations for children under 6 years are encourage to brush their teeth under the supervision of an adult, fluorine concentration in children toothpastes should be at least 500 ppm, pastes should have unsweetened taste.

The vast majority of trials of fluoridated toothpastes has been conducted on coronal caries in children and adolescents and little information is available on the effect of such toothpastes on root-surface caries in adults. Preliminary results of studies are promising, but more study is required.

Several recent studies have shown that frequency of use of a fluoride toothpaste is inversely related to caries incidence, and the method of rinsing following brushing has also been shown to affect caries inhibition; thorough mouth-rinsing after brushing the teeth increases the oral clearance of fluorides and may reduce the caries-preventive effect. A number of studies have attempted to link effectiveness with the amount of toothpaste habitually used on the brush, but there is no evidence so far that the two are related.

In some parts of the world school-based tooth-brushing programmes with fluoridated toothpastes are in place, and programmes involving fluoride application using a chewing-stick (*miswak*) are beginning to be developed in communities where this form of tooth-cleaning is commonly practised.

Conclusions:

1. Every effort must be made to develop affordable fluoridated toothpastes for general use in developing countries. Since the use of fluoridated toothpastes is a public health measure, it would be in the ultimate interest of countries to exempt them from the duties and taxation applied to cosmetics.

2. Full studies should be made of toothpastes with lower levels of fluoride that are manufactured especially for use by children.

3. Fluoridated toothpaste tubes should cary advice that for children under the age of 6 years brushing should be supervised and only a very small amount (less than 5 mm) should be placed on the brush or the chewing-stick. Research on methods of controlling the amount of toothpaste placed on the brush (for example, by restricting the size of tube orifice and size of brush) should be encouraged.

4. The use of toothpastes with candy-like flavours or containing fluoride at 1500 ppm or more by children under 6 years of age should not be encouraged.

5. Further research on the effectiveness of fluoridated toothpastes on root-surface caries is required.

6. Everyone should be encouraged to brush daily with a fluoride toothpaste.

7. The effectiveness of other methods of using fluoridated toothpaste (such as supervised school tooth-brushing and chewing-stick programmes) should be assessed and their adoption encouraged where they are appropriate.

Conclusions about topical use of fluorides:

1. Professionally applied and self-administered topical fluorides are indicated for persons and groups with moderate and high caries activity and for patients with special needs, especially in low-fluoride communities.

2. Fluoride varnishes have comparable caries-reduction benefits to other forms of topical fluorides and their wider use should be encouraged.

3. Glass ionomer cements have been shown to provide sustained fluoride levels in the oral cavity, and merit further research.

4. In low-fluoride communities, school-based fluoride rinsing programmes are recommended, but their adoption should be based on the cost of implementation and the caries status of the community.

5. Fluoride mouth-rinsing is contraindicated in children under 6 years of age.

DENTAL FLUOROSIS IN THE PREVENTION OF CARIES

Epidemiological studies have found that at a content of fluoride 1 mg per liter of drinking water, along with a lower intensity compared to the caries areas where fluoride in water is insufficient, there was dental fluorosis in approximately 10 % of the population in a very easy form without causing any anxiety. This prevalence of dental fluorosis is considered acceptable. However, with the advent of additional fluoride source, such as toothpastes, misuse, for example, the use by children under 6 years of age, can cause excessive intake of fluorine and cause aesthetically unacceptable forms of fluorosis.

The Republic of Belarus has a program for children which includes fluoridated salt use (T. N. Terekhova, 1999). Also, as in case of drinking water fluoridation, small children should not be recommended use of fluoride toothpaste, especially intended for adults or unknown origin and without indication of the fluoride concentration. Also prescribing of fluoride tablets and drops for children and adults is dangerous in the area where fluoridation of water or salt is perfomed. Such a prevention can lead to the development of chronic intoxication of organism with fluorine, manifested dental fluorosis lesions of other vital organs and systems.

In connection with these problems, many countries are regularly conducted epidemiological population surveys to detect possible dental fluorosis using highly sensitive diagnosis indexes, such as DDE. If fluorosis is revealed in the course of such studies in the population, then measures must be taken to reduce children intake of fluoride during tooth development period.

MULTIPLE FLUORIDE EXPOSURE

Most clinical trials involving the use of fluorides in caries prevention have tested a single product. In many parts of the world, however, exposure to fluoride from multiple sources is the rule rather than the exception: people in fluoridated areas brush their teeth with fluoridated toothpastes, and people anywhere can have a significant, but usually unknown, intake of fluoride from food and drink in addition to their use of fluoridated toothpaste.

Exposure to multiple sources of fluoride can be beneficial or undesirable. It can be beneficial in the sense that fuller advantage is being taken of the several ways in which fluorides act to prevent caries, but it can also increase the potential for fluorosis. Some multiple exposure is controlled, as when a dentist applies fluoride gel to a caries-susceptible patient who is using a fluoridated toothpaste, but some exposure, for example to fluoride in food and drinks, is not. It is uncontrolled exposure to fluoride, sometimes from unsuspected sources, that is the principal public health concern. Periodic assessment of total fluoride intake in a population, as well as regular monitoring of fluorosis prevalence and severity in children, enables the public health administrator to determine whether further action is called for.

Use of more than one form of fluoride in a caries-prevention programme usually provides additive benefits, but sometimes the cost-effectiveness is low. For example, if fluoride mouth-rinsing is introduced to children with low to moderate caries activity who drink fluoridated water and brush regularly with fluoridated toothpaste, the minor additional benefit may be not worth the operational costs of the programme. By contrast, fluoride mouth-rinsing among children with high caries prevalence who have no other exposure to fluoride would clearly be cost-effective. Dental public health administrators should be aware of the total fluoride exposure in the population before introducing any fluoride programme for caries prevention. The likely cost-effectiveness of any such programme has to be judged in the light of existing exposure and caries prevalence in the target population.

Conclusions:

1. Exposure to fluoride from multiple sources in young children, whether controlled or uncrontrolled, can be both beneficial in terms of reduced caries and undesirable in terms of dental fluorosis.

Dental public health administrators should be aware of the total fluoride exposure in the population before introducing any additional fluoride programme for caries prevention, and the cost-effectiveness of such programmes should be carefully considered.

Recommendations:

1. There is a need to carry out detailed fluoride mapping for existing water sources, as well as hydrological studies to show flow lines and hydrogeochemical surveys in areas where fluorosis is endemic. Governments in the affected areas should establish clear guidelines on exploitation of groundwater so that sinking boreholes in high fluoride zones can be avoided.

2. Countries that have industries that emit fluoride into the atmosphere or have mines of fluoride-rich minerals should introduce and enforce environmental protection measures.

3. Dietary practices that increase the risks of infants and young children being overexposed to fluoride from all sources should be identified and appropriate action taken.

4. Dental fluorosis should be monitored periodically to detect increasing or higher-than-acceptable levels of fluorosis. Action should be taken when fluorosis is found to be excessive by adjusting fluoride intake from water, salt or other sources. Biomarkers should be used, where practical, to assess current fluoride exposure to predict further risk of fluorosis.

5. In view of the endemic nature of unsightly dental fluorosis in a number of regions, research on the development of affordable technology for partial defluoridation in households and communities is recommended.

6. The effectiveness of all caries-preventive programmes should be regularly monitored.

7. Community water fluoridation is safe and cost-effective and should be introduced and maintained wherever it is socially acceptable and feasible. The optimum water fluoride concentration will normally be within the range 0.5–1.0 mg/l.

8. Salt fluoridation, at a minimum concentration of 200 mg/kg of F, should be considered as a practical alternative to water fluoridation.

9. Encouraging results have been reported with milk fluoridation but more studies are recommended.

10. Fluoride tablets and drops have limited application as a public health measure. In areas with medium to low caries prevalence a conservative prescribing policy should be adopted: a dose of 0.5 mg F-/day should be prescribed for individuals at risk from the age of 3 years. In areas with high caries prevalence, a dosage regimen should be used, starting at 6 months of age. that takes into account the fluoride content of the drinking-water.

11. Only one systemic fluoride measure should be used at any one time.

12. Because fluoridated toothpaste is a highly effective means of caries control, every effort must be made to develop affordable fluoridated toothpastes for use in developing countries. The use of fluoride toothpastes being a public health measure, it would be in the interest of countries to exempt them from the duties and taxation applied to cosmetics.

13. Fluoridated-toothpaste tubes should carry advice that, for children under 6 years of age, brushing should be supervised and only a very small amount (less than 5 mm) should be placed on the brush or chewing-stick. The caries-preventive effectiveness of toothpastes with lower levels of fluoride, manufactured especially for use by children, should be fully studied.

14. Fluoridated toothpastes with candy-like flavours and toothpastes containing fluoride at a concentration of 1500 ppm or more are not recommended for use by children under 6 years of age.

15. In low-fluoride communities, school-based brushing and mouthrinsing programmes are recommended, but their adoption should be based on the cost of implementation and the caries status of the community. Fluoride mouth-rinsing is contraindicated in children under 6 years of age.

16. Further research on the effectiveness of fluoride in preventing root-surface caries is recommended.

ROLE OF NUTRITION IN COMMUNITY PREVENTION PROGRAMS

Diet plays an important role in preventing oral diseases including dental caries, dental erosion, developmental defects, oral mucosal diseases, craniofacial development and, to a lesser extent, periodontal disease. Dental diseases impair quality of life and have a negative impact on self-esteem, eating ability and health, causing pain, anxiety and impaired social functioning. Tooth loss reduces the ability to eat a nutritious diet, the enjoyment of food and confidence to socialize.

Consuming a healthy diet throughout the life-course helps to prevent malnutrition in all its forms as well as a range of noncommunicable diseases (NCDs) and conditions. However, increased production of processed foods, rapid urbanization and changing lifestyles have led to a shift in dietary patterns. People are now consuming more foods high in energy, fats, free sugars and salt/sodium, and many people do not eat enough fruit, vegetables and other dietary fibre such as whole grains.

Promotion of sound dietary practices is an essential component of caries management, along with fluoride exposure and oral hygiene practices.

Fermentable carbohydrates interact dynamically with oral bacteria and saliva, and these foods will continue to be a major part of a healthful diet. Dental health professionals can serve their patients and the public by providing comprehensive oral health care and by promoting lifestyle behaviors to improve oral and general health within the time constraints of their practice. Dietary advice given should not contradict general health principles when providing practical guidance to reduce caries risk.

INFLUENCE OF NUTRITION ON ORAL DISEASES

Diseases of the oral mucosa

The first signs of deficiency of some micronutrients, for example the B-vitamins, are seen in the mouth and include glossitis, chelitis and angular stomatitis.

Oral cancer is the eighth most common cancer in the world; its prevalence is high in developing countries and is increasing in some developed countries, such as Denmark, Germany, Scotland as well as in eastern Europe. Diet is a preventable risk factor for oral cancer. Trials of individual nutrients including iron, selenium and vitamins E, A and beta-carotene have produced equivocal results, but several case control studies have shown a protective role of vitamin C. The report “Diet nutrition and the prevention of chronic diseases” stated that there was convincing evidence that scalding hot foods and drinks increased the risk for oral cancer and an associa-

tion with consumption of char-grilled foods has been found. Although wholegrain foods may be protective, the most conclusive evidence exists for a protective role of fruits and vegetables. A number of epidemiological studies have shown that the risk of oral cancer decreases with increasing fruit and vegetable intake. In a large group study in the USA, the risk of cancer was decreased by 40–80 % in people with a high intake of fruits and vegetables compared with those with a low intake. The evidence indicates a stronger effect of fruits, in particular citrus fruits. However, prospective dietary intervention trials are lacking, probably due to the methodological complexities of undertaking such studies.

Periodontal disease

Periodontal disease (gum disease) progresses more rapidly in undernourished populations; the role of nutrition in maintaining an adequate immune response may explain this observation. Periodontal disease is associated with an increased production of reactive oxygen species which, if not buffered sufficiently, cause damage to the host cells and tissues. Antioxidant nutrients, for example, ascorbic acid (vitamin C), beta-carotene and alpha-tocopherol (vitamin E) are important buffers of reactive oxygen species and are found in many fruits, vegetables, grains and seeds. Current research is investigating the potential protective role of antioxidant nutrients in periodontal disease. However, apart from severe vitamin C deficiency, which may result in scurvy-related periodontitis, there is as yet no strong evidence for an association between diet and periodontal disease.

A high sucrose intake is associated with increased plaque volume due to the production of extracellular glucans, and there is a strong association between plaque volume and gingivitis. Human intervention studies have shown higher plaque volumes and increased gingivitis with high sucrose diets compared with low sucrose diets. However, Gaengler et al. pointed out that "the maximum reduction in sugar in the diet within the limits of practicability is not capable of preventing the development of gingivitis".

Acute necrotising gingivitis and noma

Therefore, malnutrition can intensify the severity of oral infections and may lead to their evolution into lifethreatening diseases. The impact on oral health of malnutrition was recently reviewed by Enwonwu et al. Among the suspected causative factors are increased oral burden of free glucocorticoids and impaired host defence of saliva. No inflammatory oral lesions underscore the association between malnutrition and oral health as lucidly as acute necrotising gingivitis (ANG) and noma (cancrum oris). ANG is a craterlike lesion involving the interproximal gingival papillae and predominantly affects impoverished young children (3–10 years of age) who are generally immunocompromised by malnutrition and common tropical infections. If not promptly treated, ANG and other oral inflammatory lesions in malnourished children may evolve into noma (cancrum oris). This is a dehumanising orofacial gangrene that destroys the soft and hard tissues of the oral and paraoral structures.

Interrelationship between nutritional status and HIV/AIDS

There is a strong relationship between immune status and oral symptoms of human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). Poor nutritional status may compound the impaired immune status associated with HIV, possibly contributing to more rapid development of oral symptoms including ulceration, candidiasis, drug-induced xerostomia and neoplasms. Oral manifestations of HIV exacerbate poor nutritional intake as a result of oral pain, dry mouth, dysphagia and, in case of neoplasms, obstruction. Nutritional intervention together with oral care is essential to prevent the patient becoming severely nutritionally compromised.

Dental erosion

Dental erosion is an irreversible loss of dental hard tissue (enamel and dentine) that is chemically etched away by acids in a process not involving bacteria. Poor salivary flow or salivary deficiencies are thought to make some individuals more susceptible to acid challenges. Low salivary flow rate or inadequate buffering capacity are factors that exacerbate erosion. Intrinsic acids come from vomiting and regurgitation. Extrinsic acids come from the diet, e.g. citric acid, phosphoric acid, ascorbic acid, malic acid, tartaric acid and carbonic acids found in fruits and fruit juices, soft drinks — both carbonated and still, some herbal teas, dry wines and vinegar-containing foods. The critical pH of enamel is 5.5 and therefore any drink or food with a lower pH may cause erosion. Erosion reduces the size of the teeth and in severe cases leads to total tooth destruction. Extensive dental erosion requires expensive restorative treatment.

Observational studies in humans have shown an association between dental erosion and the consumption of a some acidic foods and drinks, including consumption of fruit juice, soft drinks, vinegar, citrus fruits and berries. Age-related rise of dental erosion has shown to be greater in those with the highest intake of soft drinks. Animal studies have shown that fruits and soft drinks cause erosion, although fruit juices were 3–10 times more destructive than whole fruit. WHO concluded that consumption of soft drinks was a probable cause of dental erosion and that citrus fruit were a possible cause, however, there was insufficient evidence to incriminate other fruit. However, in general such studies have shown that beverages with a high titratable acidity or a pH of 0,4 can lead to erosion. Citric, malic and tartaric acids are particularly erosive and carbonic acid is the least erosive. However, Meurman and Cate argue that present data does not allow the ranking of different acids.

Developmental defects of the enamel

Nutritional status affects the teeth before the eruption, although this influence is much less important than the post-eruptive local effect of diet. An enamel defect that is common in undernourished communities is linear enamel hypoplasia (LEH). This usually occurs in primary incisors and is characterized by a horizontal groove usually found on the labial surface that becomes stained after the eruption. Several investigators have shown that the presence of enamel hypoplasia is associated with undernutrition and its prevalence increases with the severity of undernu-

trition. However, the specific mechanism for an effect of diet on the development of enamel hypoplasia was not understood until the 1980s when the association between hypocalcaemia and hypoplasia was discovered. Hypocalcaemia is common in undernutrition and is associated with diarrhoea.

Deficiencies of vitamins D and A and protein–energy malnutrition are associated with enamel hypoplasia and salivary gland atrophy, both of which increase susceptibility to dental caries. Vitamin D deficiency provides a marked effect on the development of the teeth. Dogs reared on diets that were deficient in vitamin D had delayed development of teeth and teeth that were poorly calcified and poorly aligned. Many of the teeth showed signs of hypoplasia.

In more recent trials, classrooms in Canada were installed with full spectrum lighting that has a high UV output and hence promotes vitamin D synthesis in the skin. Children attending schools with the full spectrum lighting were found to develop fewer caries over the two year study period compared with children attending classrooms with conventional lighting.

Among the diet-related oral problems we can mention developmental defects of tooth enamel which may be due to the following:

– Gluten intolerance;
– Dioxide in breast milk;
– vitamin A or D deficient diet.

Excessive fluoride ingestion while enamel is forming (up to the age of 6 years for permanent dentition) may cause dental fluorosis.

Influence of nutrition during tooth development on future caries susceptibility

Undernutrition may exacerbate the development of dental caries in three ways. First, as already mentioned, it contributes to the development of hypoplasia which in turn increases caries susceptibility. Secondly, it causes salivary gland atrophy, which results in reduced saliva flow and altered saliva composition. This reduces the buffering capacity of the saliva and increases the acidogenic load of the diet. There is also evidence that deficiency of vitamin A causes salivary gland atrophy and a consequently reduced saliva flow. Thirdly, undernutrition delays eruption and shedding of teeth which affects the caries experience at a given age.

With the exception of data on fluoride, there are few data relating dietary components to caries risk in humans. Several investigators have found a beneficial effect of supplemental vitamin D in children up to the age of 10 (McDonald, 1985b) and have suggested that the optimal daily intake is approximately 400 IU (Shaw, 1952). However, other studies have produced conflicting findings (Navia, 1970).

McDonald (1985b) hypothesized that protein malnutrition disturbs IgA salivary concentration, thereby increasing risk of caries development.

Post-eruptive effect of diet on the development of dental caries. There is a wealth of evidence to show the role of dietary sugars in the aetiology of dental caries. Dental caries occurs because of demineralization of enamel and dentine by organic acids formed by bacteria in dental plaque through the anaerobic metabo-

lism of dietary sugars. Both the presence and the extent of S. mutans infection in children are associated with caries risk. Köhler et al. (1986) reported that in children infected with S. mutans before age 2, caries prevalence is 8 times greater than in children not infected until age 4. Similarly, children who are more heavily infected tend to develop more caries than children with lower counts (Köhler et al., 1984).

The evidence comes from many different types of investigations:

1. Human observational studies
2. Human intervention studies (clinical trials)
3. Animal experiments
4. Plaque pH studies
5. Enamel slab experiments
6. Incubation studies in vitro.

In general, information from different types of studies provides an overall picture of the cariogenic potential of different dietary carbohydrates. The strength of the evidence incriminating sugars in the aetiology of dental caries comes from multiplicity of studies rather than any study separate.

SUGARS

To most people the term "sugar" refers to the common household foodstuff table sugar (sucrose). Yet sucrose is only one of many naturally occurring sugars used in the human diet. Technically the term "sugars" applies to two classifications of carbohydrates: free-form monosaccharides (simple sugars) which commonly include **glucose, fructose, and galactose** and disaccharides (two simple sugar molecules linked together) which commonly include **sucrose, lactose, and maltose**. Naturally occurring sugars are available in fruit, vegetables, grains, and dairy foods.

Human observational study

Despite the marked decline in dental caries in developed countries over the past 30 years, the prevalence remains high and favourable trends are halting. In developing countries, dental caries has increased where exposure to dietary sugars has been noticed.

Human observational study. In countries with a level of sugar consumption less than 18 kg/person/year (equivalent to ~50 g/person/day), caries experience is consistently low. The reduced availability of sugar during the Second World War showed a reduction in dental caries, which subsequently increased after war.

Confectionery industry workers and children with chronic diseases requiring long-term sugar-containing medicines have higher intensity of caries. Studies have shown up to 71 % higher caries in confectionery industry workers than factory workers from other industries. This is observed in countries such as Finland where fluoride application is high.

Low dental caries experience has been reported in groups of people who have a habitually low intake of dietary sugars; for example, children of dentists, children in institutions where strict dietary regimens are followed and children with hereditary fructose intolerance (HFI).

Isolated communities with a traditional diet low in sugars have very low levels of dental caries (even when the traditional diet is high in starch). On adopting a more "westernized" diet, i.e. a diet high in sugars, such populations have experienced a marked increase in dental caries. Examples of this trend have been reported among the Inuit in Alaska, in Ethiopia, Ghana, Nigeria, Sudan and Tristan da Cunha (table 3, fig. 3).

Table 3

Consumption (g/person per day) of Sugar and flour containing foods in Tristan da Cunha

	1938	1966
Sugar	1.8	150
Cakes and biscuits	0.5	24
Jam and condensed milk	0.2	20
Bread	1.7	
White flour		110
Sweets and chocolates	0	50

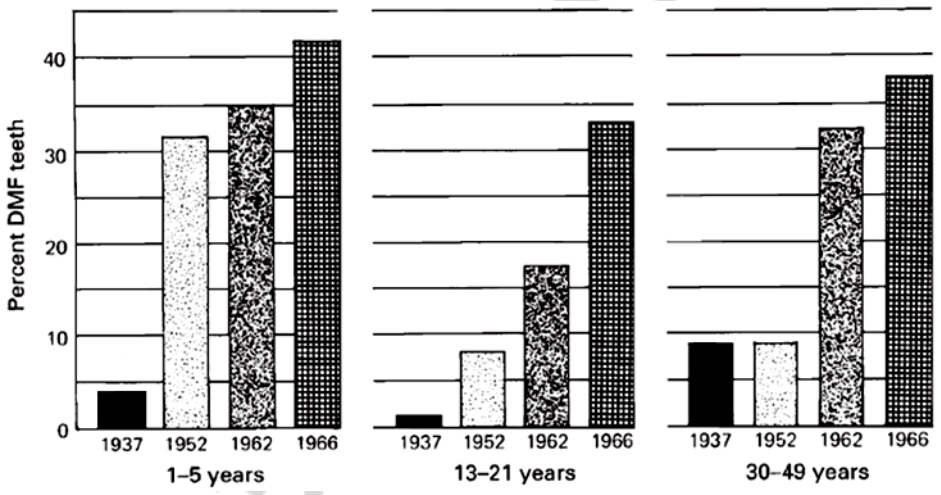


Fig. 3. Caries severity (per cent DMFT) in three age groups of inhabitants of Tristan da Cunha at four examinations between 1937 and 1966

It has shown that consuming 75 to 100 grams of simple sugars (about 20 teaspoons of sugar — the amount found in two-and-a-half average 12 ounce cans of soda) can suppress the immune responses of the body considerably.

Conclusions from human observational studies of the sugars/caries relationship:

– A positive relationship exists between per capita sugar availability and DMFT at age of 12 years

– A marked increase in the prevalence and severity of dental caries has been observed in populations who changed their traditional way of eating and adopted a westernized diet, high in sugars

– Sub-groups of the population who habitually consume products high in sugar have been shown to have higher levels of dental caries compared to the general population

– Sub-groups of the population who habitually consume products low in sugar have been shown to have lower levels of dental caries compared with the general population

– Caution is needed when interpreting the findings of cross-sectional studies that have compared diet to levels of dental caries at one time point, since caries develops over time. It may be the diet several years previous which is responsible for current disease levels

– Studies with a longitudinal design, that measure diet and relate it to change in levels of dental caries over time provide stronger evidence

– Human intervention studies provide the strongest evidence for an association between diet and diseases, however, these are difficult to conduct from an ethical and logistic point of view.

The NDNS of 1.5–4.5 year old children (Hinds and Gregory 1995) showed that the strongest determinants of dental health were social factors such as the level of household income and level of education of mothers. However, when social factors were controlled for, associations were also found between household expenditure on confectionery, frequency of consumption of confectionery and soft drinks, and high average intake of sugar confectionery and soft drinks.

In the era of exposure to fluoride Grindefjord et al. observed caries levels in a group of young children between the ages of 1 to 3.5 years in the primary dentition (Grindefjord et al. 1996). A significant relationship between the consumption of confectionery and sugar-containing beverages and caries increment was found.

The Michigan Study was carried out in the USA between 1982 and 1985 and it studied the relationship between sugars intake and dental caries increment over three years in children initially aged 10–15 years (Burt et al. 1988). This study also found weak relationships between the amount and frequency of intake of dietary sugars. Children who consumed a higher proportion of their total dietary energy as sugars had a higher caries increment for approximal caries, though there was no significant association between sugars intake and pit and fissure caries. The frequency of intake of sugars or sugar-containing foods (with >15 % sugars) was not related to caries increment but the amount of sugars eaten between meals was related to approximal caries. When children were divided into two groups a tendency towards more frequent snacking was seen in children with high intensity of caries.

Numerous cross-sectional epidemiological studies of the association between intake of sugars with dental caries have produced equivocal results. However, cross-sectional studies may not give a true reflection of the role of diet in the development of caries because the diet of previous years is responsible for current level of caries. A longitudinal study design that monitors changes in levels of caries and relates them to diet is more appropriate.

Many earlier studies failed to show a relationship between intake of sugars and development of dental caries because their methodological design was poor, they used unsuitable methods of dietary analysis and lacked sufficient statistical power.

Few ***intervention*** studies have investigated the effect of sugars on caries. The **Vipeholm** study, conducted at the adult mental institution in Sweden between 1945 and 1953, investigated the effects of consuming sugary foods of different "stickiness" and at varyious frequencies on the development of caries. It was concluded that sugar had little effect on caries development if ingested with meals no more than four times a day. Increased frequency of consumption of sugar between meals was, however, associated with a marked increase in dental caries. It was also found that the increase in progression of dental caries halted on withdrawal of sugar from the diet.

Main conclusions of the Vipeholm study:

– Sugar intake, even when consumed in large amounts, had little effect on caries increment if it was ingested not more that four times a day at mealtimes only

– Consumption of sugar in-between meals was associated with a marked increase in dental caries

– The increase in dental caries activity disappears on withdrawal of sugar-rich foods

– Dental caries experience showed wide individual variation.

A second important intervention study was the **Turku** study. This was a controlled longitudinal study carried out in Finland in the 1970s (Scheinin and Makinen 1975). The study investigated the effect of almost total substitution of sucrose in a normal diet with either fructose or xylitol on caries development, but the results can be used as indirect evidence for the impact of sugar on the development of caries. An 85 % reduction in dental caries was observed in the xylitol consuming group (fig. 4).

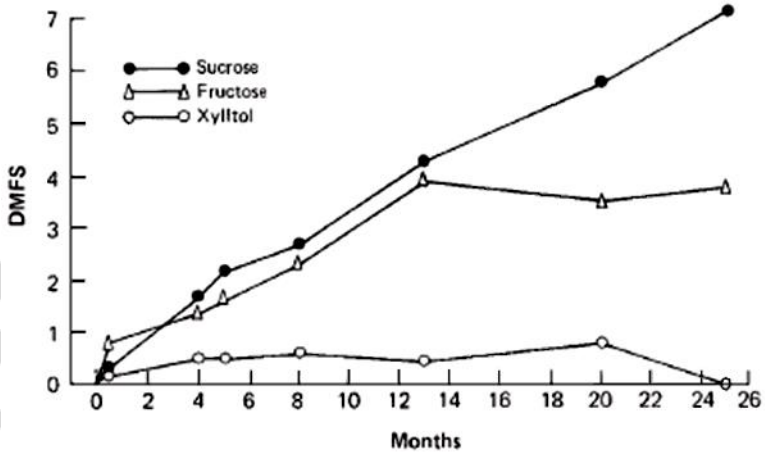


Fig. 4. Dynamics of DMFT in Turku study

Why little is known about the cariogenic potential of specific carbohydrate-containing foods: (1) because of cost and ethical considerations, few studies of

specific foods and caries in humans have been or will be conducted and (2) findings from such studies are difficult to generalize to noninstitutionalized humans.

Animal experiments. The cariogenic role of oral microflora was first noted in studies of rats delivered by Caesarean section and maintained under sterile conditions. The germ-free rats were caries-free from birth and remained so, even when fed a cariogenic diet.

Animal experiments allowed to investigate the relationship between dietary sugars and dental caries most commonly use the rat model; however, mice, hamsters, and monkeys have also been used. Animal experiments have enabled study of different types, concentrations, and frequencies of carbohydrates and sugars under specified conditions. It would not be possible to test such dietary regimens in humans due to problems of palatability and compliance.

As in humans, the cariogenicity of dietary carbohydrates in animal models appears to be influenced by the frequency, form, and composition of the diet. For example, frequent consumption of carbohydrates markedly accelerates caries formation in rats.

Reduction of dietary calcium in rats increased caries risk, whereas the addition of calcium chloride, calcium gluconate, or phosphorus decreased the risk. There has been no confirmation of these findings, however. A number of trace elements, including aluminum, barium, boron, cadmium, copper, lead, and selenium, have also been examined for cariostatic potential, but again, no definite data have been obtained.

For example, although most types of phosphates effectively reduce caries in rats when added to sucrose-containing diets, phosphate supplementation in the human diet has been markedly unsuccessful in reducing caries incidence.

The importance of the local effect of sugar in the mouth was clearly demonstrated in studies where rats were fed a cariogenic diet either conventionally via the stomach or by a stomach tube (table 4). The salivary glands of some of the animals in each group had been removed. The results demonstrate (1) the importance of the local presence of sugars in the mouth and (2) the important role of saliva in protecting against dental caries.

Table 4

The mean number of carious lesions in rats fed a cariogenic diet either conventionally or by stomach tube. The salivary glands of some of the animals in each group had been removed. Number of animals in each group is given in parentheses

	Conventional	Tube fed
Intact	6.7 (13)	0 (13)
Desalivated	28.8 (4)	0 (3)

Animals fed ad libitum consumed 11.7 g of food per day. Control group consumed 6 g. The results show that frequency of eating a cariogenic diet is more important than the overall amount consumed. Another important factor is the amount of time between food intakes. In an experiment where animals received 18 portions of food per day, one group received 3 × 6 portions, with no time between consump-

tion of the 6 portions. The second group had a 30 minute interval between each of the 18 portions. Caries development was greater in the latter group.

Animal experiments have also been used to examine the effect of concentration of sugars in the diet. A large number of studies have shown that diets containing some sugar (~10 %) cause more caries than sugar-free diets, further increases in caries have not always been seen significant when the sugar concentration is increased above 10 %. Results have varied due to the type of diet used and also according to whether or not the rats were super infected with cariogenic organisms. Caries severity has been shown to increase with increasing sugars concentration up to a level of 40 % in rats super infected with S. mutans and Actinomyces viscosus.

There was no difference in the carcinogenicity of glucose and fructose. In monkeys, sucrose has been shown to have a similar carcinogenicity to glucose/fructose mixes, whereas fructose was less cariogenic than sucrose.

Animal studies showed:

– A clear relationship between frequency of consumption of a cariogenic diet and severity of dental caries

– Increasing caries with increasing sugars concentration

– Little difference in the cariogenicity of glucose, fructose and maltose and increased cariogenicity of sucrose only when animals are super infected with S. mutans.

Enamel slab experiments

Enamel slab experiments use oral appliances that hold slabs of bovine or human enamel. Plaque is formed on the enamel slabs which remain in the mouth for 1 to 6 weeks (fig. 5). The slabs are exposed to the dietary factor being tested, by either consumption of food with the slabs in situ or by removal of the appliances several times a day to dip into vessels containing the dietary test substances. Changes in enamel hardness or degree of demineralization may be measured at the end of the experimental period. Enamel slab experiments have shown that sugars cause demineralization, while non-fermentable non-sugar sweeteners aid remineralization.

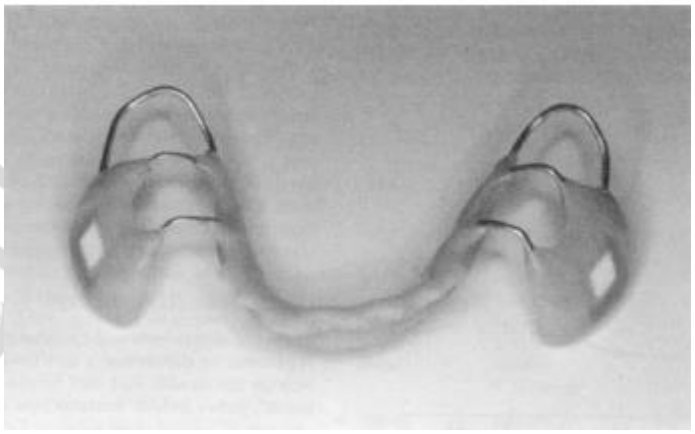


Fig. 5. An example of an acrylic resin appliance showing two buccal flanges each containing a terylene mesh-covered slab of enamel

Increasing the concentration of sugars, and the frequency of exposure to sugars increases demineralization. The advantage of enamel slab experiments over in vitro incubation experiments or in vivo plaque pH experiments is that they measure demineralization and not just acidogenic potential but also account for the protective role of saliva.

Plaque pH studies

Plaque pH studies measure changes in the pH of plaque following consumption of a carbohydrate or carbohydrate-containing food. They measure acidogenic potential, which is taken as an indirect measure of cariogenic potential, although acidogenicity does not take into account protective factors in consumed food and, salivary factors that may modify the carcinogenicity of food.

The resting pH of dental plaque was mostly between pH 6.5 and 7, the term resting plaque refers to plaque 2–2.5 hours after the last intake of carbohydrate. But when the plaque is exposed to sucrose or glucose the pH of plaque falls rapidly below the critical value within 2–5 minutes.

The value of pH 5.5 has become accepted as critical pH below which dental enamel will begin to dissolve because the environment is no longer saturated with enamel mineral. This rapid fall was then followed by slow recovery over the next 30–60 minutes. The plot of plaque pH against time has become known as the Stephan curve (fig. 6).

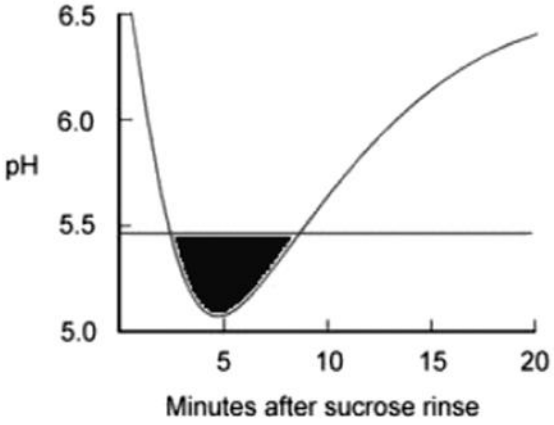


Fig. 6. Stephan curve

The cariogenicity of plaque depends on its ability:

– to adhere to the teeth;
– to resist dissolution by saliva;
– to protect bacterial acids from salivary buffering.

The rapidity with which the pH falls is a reflection of speed at which sucrose comes diffuse with plaque and the activity of the concentration of enzymes produced by the great number of bacteria in the plaque. The slow rate of recovery to the resting pH, critical factor in caries production depends mainly on:

– Rapid production of high concentration of acids within the plaque, temporarily overcomes local buffering.

– Escape of acids in to saliva, delayed by the diffusionlimiting properties of plaque and its thickness.

– Diffusion of salivary buffers in to plaque hampered by the diffusion-limiting properties of plaque and its thickness.

– Continued sugar production from bacterial intracellular polysaccharides.

Carbohydrates in various drinks are eliminated within 5 minutes while sugar containing chewing gums, toffees, lozenges generally give high oral sucrose concentration and clearance time is 40 minutes for chewing gum and 15–20 minutes for other sweets. The caries producing potential could possibly be reduced by modifying their physical properties (roughage, adhesiveness, solubility).

Practical way to speed up carbohydrate clearance are:

– tooth brushing immediately after the meal, or

– induction of rapid salivary flow by mechanical or gustatory stimuli through eating tough or highly flavored foods at the end of meals.

Chewing sugar free chewing gum or peanuts immediately after eating sugar also speed up sugar clearance and neutralization of plaque acid through saliva stimulation while mouth rinsing with water has a very limited effect, partly because it is generally done too late: two minutes after a sucrose challenge, the sugar concentration in saliva is usually lower than that in plaque so rinsing with water at that time would not be expected to reduce the diffusion of sugar into plaque, unless the sugar clearance were excessively slow, as in xerostomic subjects. The advantages of mouth rinsing after meal is that it also helps to remove sugars in solution and food debris.

This makes the method well suited for testing the non-carcinogenicity of foodstuffs. For example, if a product does not reduce plaque pH below 5.7 on consumption and for 20 minutes following consumption it may be categorized as "safe for teeth".

Snacks, meal patterns, and plaque pH

Plaque pH studies that have been used to rank the acidogenicity of snack foods have shown that boiled sweets give the lowest plaque pH (~5.2), sweetened tea and coffee also give low pH values, and foods sweetened with non-sugar sweeteners (e.g. sugar-free chewing gum (pH ~6.8), diabetic chocolate sweetened with sorbitol) and salivary stimulants such as peanuts give the highest pH values. Figure 7 illustrates the difference in the acidogenicity of sucrose-containing and sorbitol-containing chocolate.

Studies using the indwelling glass electrode system have shown starchy staple foods such as wheat-flakes and bread to produce deep pH responses, similar to those produced by sucrose. Eating hard cheese following a sugar snack (pears in syrup) has been shown to almost abolish the fall in pH that usually accompanies sugar consumption. When sugared coffee was consumed in place of hard cheese, the pH was depressed further. The effect of cheese is probably due to the stimulation of saliva by this highly flavoured food and its low carbohydrate (lactose) content. Peanuts and sugar-free chewing gums are also good salivary stimulants that reduce the pH fall if consumed following a sugarcontaining meal or snack. Apples have little benefit compared with peanuts. It is often advised to consume sugar-rich

foods at mealtimes rather than alone, in between meals. This is because, when consumed with other foods the effect on pH is mimimized probably due to (1) a dilution effect and (2) the increased salivary flow rate due to mastication of other foods.

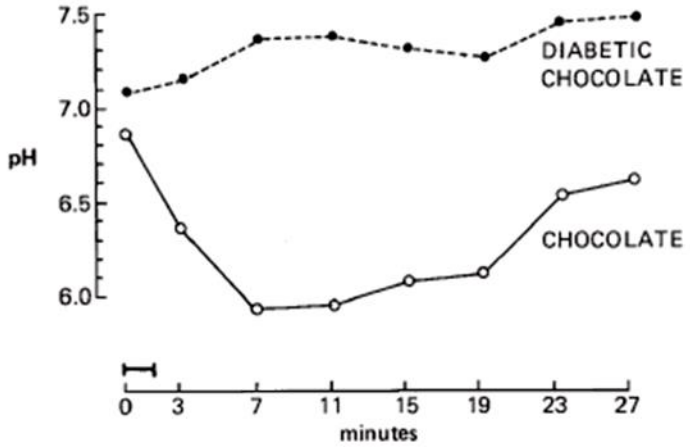


Fig. 7. Stephan curves produced by dark ("plain") chocolate (containing sugar) and "diabetic" chocolate (containing sorbitol)

The breakfast included sugar-containing coffee, a boiled egg, and a crisp bread with butter. The smallest drop in pH was observed when all three items were consumed together (fig. 8, curve F). The largest drop in pH was observed when the sugared coffee was consumed alone (fig. 8, curve E). These studies clearly show how one product can influence the acidogenicity of another.

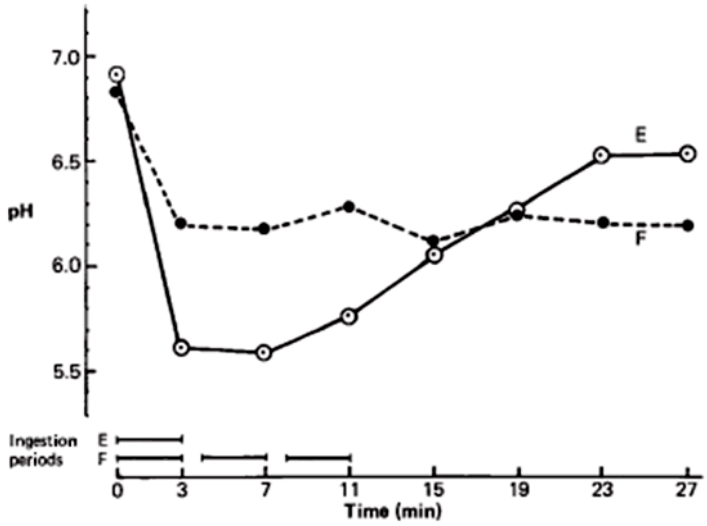


Fig. 8. Stephan curves produced when sugared coffee was taken alone (E) or taken together with the other two non-acidogenic foods (F)

Main conclusions from plaque pH studies:

– Measure acidogenic potential, is indirect measure of cariogenicity

– Measure the pH of plaque using either an indwelling electrode that measures pH in situ or by removing plaque samples and measuring the pH in vitro

– Acidogenicity is expressed as the area of the time/pH graph ("Stephan curve"), the minimum pH reached and/or the time for which pH drops below 5.5 (the "critical pH").

Incubation experiments

Incubation studies are simple in vitro tests that measure if plaque bacteria can metabolize carbohydrate in test food to produce acid. Pure cultures of micro-organisms may also be used in place of whole plaque. Rapid acid production and/or a low final pH is interpreted to mean that food is potentially cariogenic, while a slow rate of acid production or higher final pH is likely to be of little clinical significance. All mono and disaccharides (10 % solutions) produce a final pH below 4.5 when incubated with plaque. In some incubation experiments, teeth, sectioned or powdered tooth enamel, or hydroxyapatite are incubated with the test substance and the plaque micro-organism in order to simulate the caries process. Potential cariogenicity is estimated from the extent of calcium and phosphorus release following incubation. Such studies have indicated that sugars content is an important determinant of the amount of mineral dissolved.

IMPORTANCE OF FREQUENCY AND AMOUNT OF SUGARS INTAKE

The importance of frequency versus the total amount of sugars is difficult to evaluate as it is hard to distinguish them from each other. An increase of either parameter often automatically gives an increase in the other, and likewise a reduction in frequency of sugar intake in the diet should result in the reduction of total sugar consumed. Data from animal studies have indicated the importance of frequency of sugars intake in the development of dental caries, and have shown that dental caries experience increases with increasing frequency of intake of sugars even when the absolute intake of sugars eaten by all groups of rats is the same. Animal studies have also shown that less caries develop as the interval between meals increases. Some human studies also suggest that the frequency of sugar intake is more important aetiological factor for caries development than the total consumption of sugar. Studies of preschool children have suggested a threshold of intake of sugars of 4 times a day after which the caries severity markedly increases.

Running contrary to the general perception that frequency of intake is more important than the amount of sugars eaten, several longitudinal studies have shown the amount of sugar intake to be more important than frequency (Burt et al. 1988, Rugg-Gunn et al. 1984). Animal studies have also been used to investigate the relationship between amount of sugars consumed and the development of dental caries and have shown a significant correlation between the sugar concentration of the food fed to rats and the incidence of dental caries (fig. 9).

The odds ratios of having DMFT of above the 80th percentile for age, increased from 1.28 for those having one soft drink per day to 1.87 for twice, and 2.79 for three or more intakes per day. First, dental caries appeared to be influenced more by frequency of sucrose intake than by total amount consumed. Second, solid forms of sugar, which are more easily retained in teeth, appear to be more cariogenic than liquid forms of sucrose.

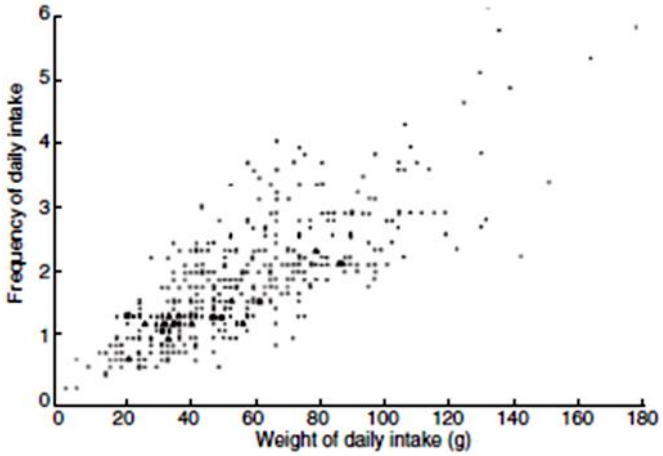


Fig. 9. The relationship between the frequency and amount of confectionery intake: frequency of intake against (intakes per day) amount of intake (g/day) in 405 12–14-year-old English children

An increase in caries incidence with increasing sucrose dose has been observed at levels ranging from 8 % (Kreitzman and Klein, 1976) to 40 % of dietary sucrose.

Summary:

– it is evident that both the frequency of intake of sugars and sugars-rich foods and drinks, and the total amount of sugars consumed are related to dental caries;

– it is also evident that these two variables are strongly associated, meaning that efforts to control one are likely to control the other;

– it is public health policy to reduce the amount of sugars consumed;

– for individuals, it is more pragmatic to advise to reduce the frequency of consumption.

Modern diets in industrialized countries contain a mix of fermentable sugars including sucrose, glucose, lactose, fructose, glucose syrups, highfructose corn syrups and other synthetic oligosaccharides (e.g. fructooligosaccharides). Oral bacteria metabolize all mono and disaccharides to produce acid. Animal studies have shown no clear evidence that the cariogenicity of mono and disaccharide differs, except lactose.

Studies in humans have also revealed the difference in the cariogenicity of some sugars; for example, the aforementioned Turku study showed no difference in caries development between subjects on diets sweetened with sucrose compared with fructose (Scheinin and Makinen 1975). Invert sugar (50 % fructose and 50 % glucose) has been shown to be 20–25 % less cariogenic than sucrose.

CLASSIFICATION OF SUGARS

There is no evidence from epidemiological studies that sugars located within the cellular structure of food are harmful to teeth; and, therefore, for dental health purposes, it is important to distinguish between these sugars and sugars in the free form. The term “added sugars” is not ideal as it excludes sugars in fruit juices and honey. The term “free sugars” has been used by the World Health Organization. In

1989, the UK Committee on Medical Aspects of Food Policy (COMA) classified sugars for dental health purposes into "intrinsic" and "extrinsic sugars" (fig. 10) (Department of Health 1989). Extrinsic sugars were sub-divided into "milk sugars" (as lactose naturally present in milk is not thought to be harmful to the teeth) and "non-milk extrinsic sugars (NMES)" which include all sugars added by manufacturer, cook, or consumer, and honey and fruit juices. In terms of dental caries, it is the intake and frequency of intake of NMES (or "free sugars") that needs to be reduced.

Much of the data that illustrate an association between intake of dietary sugars and dental caries were collected in the prefluoride era. More recent studies of the relationship between sugars and caries are confounded by the presence of fluoride but show that a relationship between sugars intake and caries still exists in the presence of fluoride.

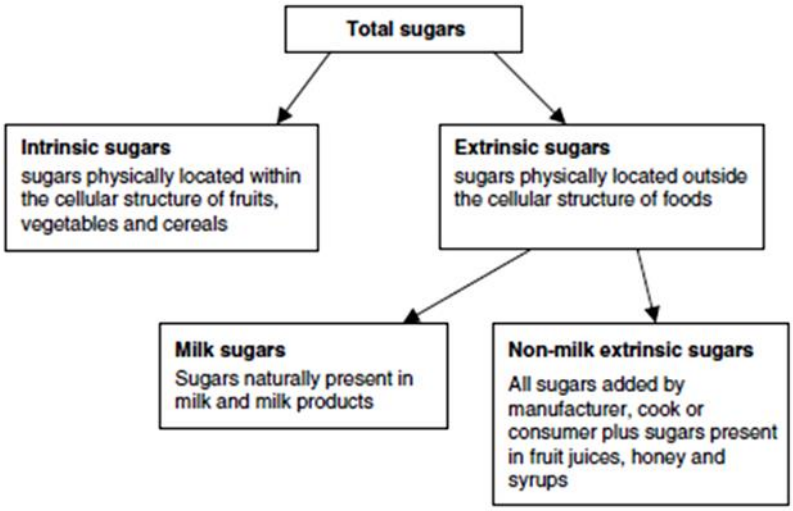


Fig. 10. Classification of sugars for health purposes: classification of the 1989 Department of Health COMA report "Dietary Sugars and Human Disease"

Marthaler concluded that within modern societies which are aware and make use of prevention, the relation between sugar consumption and caries activity still exists, and he also concludes that recent studies have demonstrated that sugar — sucrose as well as other hexoses — continues to be the main threat for dental health:

1) of whole population in some developed and many developing countries;

2) for the individual in both developed and developing countries;

3) in spite of the progress made in using fluorides and improved oral hygiene.

The conclusions of the systematic review (Burt and Pai 2001) were:

– In case of enough fluoride usage sugar consumption is a moderate risk factor for caries development; and, preventing consumption of excess sugars is a justifiable part of caries prevention if not the most crucial aspect for most people.

– Sugars consumption is likely to be a more powerful indicator for risk of caries infection in persons who do not have regular exposure to fluoride.

With widespread use of fluoride, sugars consumption still has a role to play in the prevention of caries but this role is not a strong as it is without exposure to fluoride.

STARCH

Starch constitutes a heterogeneous food group; it varies in botanical origin, it may be highly refined or consumed in its natural state; it may be consumed raw or in a cooked form — all these factors should be considered when assessing the cariogenicity of starches. It is believed that all carbohydrates cause dental caries because starches are broken down by salivary amylase releasing glucose, maltose, and maltotriose that may be metabolized by oral bacteria to produce acids. However, the evidence to support this argument is not strong. In the UK, as in many countries, current dietary guidelines for health promote increased consumption of starch-rich staple foods but limited amounts of non-milk extrinsic sugars (free sugars). It is, therefore, important to consider the cariogenic potential of starch-rich staple foods and sugars as separate issues. The following paragraphs will consider the evidence from all types of experiments relating to the cariogenic potential of starch-containing foods.

Human observational studies

Epidemiological studies have shown that starch is of low cariogenicity. People who consume high starch/low sugar diet generally have low caries experience, whereas people who consume low starch/high sugar diets have high levels of caries.

Human intervention studies demonstrated in the aforementioned Turku intake of starch was not limited and all groups ate unlimited starch, dietary starch cannot have contributed significantly to caries development in this study.

Animal experiments have shown that raw starch is of low cariogenicity regardless of the method of feeding. In studies where cooked starches have been fed ad libitum, starches caused caries but only about **one-third to one-half** the amount caused by sucrose. Carbohydrates in the form of maize or wheat starch had virtually no cariogenic activity when consumed by gnotobiotic rats and macaques. However, mixtures of starch and sucrose are more cariogenic than starch alone and the amount of caries that develops is related to the sucrose concentration in the mix.

Plaque pH studies of starch-containing foods have indicated that cooked starch or starchy foods are less acidogenic than sugars or sugars-rich foods. It must also be considered that plaque pH studies measure acid production from a substrate and do not measure caries development. This means plaque pH studies take no account of the protective factors found in some starch-rich foods.

Enamel slab experiments

There have been two reports about the effect of cooked, starch-rich foods upon the demineralization of enamel slabs under experimental conditions and both have indicated that starch causes approximately **25 %** of the demineralization seen with sucrose. Enamel slab experiments in humans have shown that raw starch does not cause demineralization.

Rugg-Gunn extensively reviewed the evidence of the relationship between starches and dental caries and come to the following conclusions:

1. Cooked staple starchy foods such as rice, potatoes and bread are of low cariogenicity in humans.

2. The cariogenicity of uncooked starch is very low.

3. Finely ground and heat-treated starch can induce dental caries but the amount of caries is less than that caused by sugars.

4. The addition of sugar increases the cariogenicity of cooked starchy foods. Foods containing cooked starch and substantial amounts of sucrose appear to be as cariogenic as similar quantities of sucrose.

NOVEL CARBOHYDRATES AND RISK OF DENTAL CARIES

Commercial production of polymers of glucose and oligosaccharides of glucose, fructose and galactose, and their use in food products is increasing. Information about the effects of these carbohydrates is therefore of great importance. Glucose polymers and non-digestible oligosaccharides are fermentable carbohydrates, however, products that contain them may be labelled as sugar-free (e.g. some chewable 'sugar-free' vitamin tablets contain fructooligsaccharides). Glucose syrups and maltodextrins are collectively known as glucose polymers and are produced by acid hydrolysis of starch. They vary in composition but contain a mixture of mono, di, tri, tetra, penta, hexa, and hepta-saccharides and alpha limit dextrins (short branched-chain saccharides). The degree of complexity is expressed as the dextrose equivalent (DE); the less complex the glucose polymer, the higher the DE. Glucose syrups have the DE of 20 or more, whereas maltodextrins are more complex and have the DE of less than 20. Glucose polymers are virtually tasteless and odourless and are used to increase the energy content of a variety of foods. They are frequently added to infant food and drinks, sports drinks, desserts, confectionery, and energy supplements to use in clinical dietetics. Glucose polymers contain traces of mono, di, and trisaccharides that may be metabolized by plaque micro-organisms. Additionally, salivary amylase may hydrolyze the longer glycolsidic chains to maltose and glucose. The extent of hydrolysis by amylase will be determined by the retention time in the oral cavity. Therefore, glucose polymers have the potential to cause dental caries but it occurs rarely. Most data come from animal, plaque pH and in vitro laboratory studies. Glucose syrup solutions have been found to be less cariogenic than sucrose solutions; however, when added to the solid component of the rat diet, no difference in caries development has been shown between rats fed glucose syrups and rats fed sucrose. In humans, substitution of sucrose with glucose syrups resulted in markedly reduced plaque scores, but the amount of plaque present is not necessarily related to caries development. Glucose syrups are present, in place of lactose, in soya infant formula, raising concern about the effect of such milks on infant caries. Plaque pH studies show no significant difference in acidogenic potential between soya infant formula and

standard infant milk. However, plaque pH studies do not account for the lower content of protective factors in soya milks and the extended time for which infants may need to remain on this formula. A maltodextrin solution (10 %) has been shown to lower plaque pH but to a lesser extent than a 10 % solution of sucrose. In the absence of evidence from human clinical trials, advice for the use of glucose polymers should be the same as that for non-milk extrinsic sugars. To safeguard dental health, it is preferable that, if consumed in between meals, maltodextrins are added only to foods and drinks that are cleared from the mouth quickly.

There is an increasing interest in the synthesis of novel oligosaccharides (e.g. prebiotics) and in isolating the transglucosylase enzymes that enable their production, not only for economical reasons but also due to potential health benefits. Many synthetic oligosaccharides are resistant to digestion and pass on to the large intestine where they encourage the growth of bifidobacteria, which are known to reduce the growth of pathogenic microorganisms.

They may, therefore, protect against diseases of the bowel. Many of the species of bacteria found in the colon are also present in dental plaque (e.g. bifidobacteria and lactobacilli), and therefore the dental health effect of these novel carbohydrates is of importance.

Isomaltooligosaccharides. S. mutans species metabolize IMOs to a much lesser extent than glucose and sucrose, and plaque pH studies in human volunteers have also shown that IMO are less acidogenic compared with glucose or sucrose, but may nevertheless result in a fall in pH to below the critical pH of 5.5. Studies in vitro have shown IMO to inhibit glucan synthesis from sucrose and inhibit the sucrosedependent adherence of S. mutans.

Fructooligosaccharides:

– Fructooligosaccharides (FOS) are also resistant to digestion in the upper gastrointestinal tract and increase the growth of bifidobacteria

– FOS are widely used in the food industry in Japan and increasingly so in the United Kingdom

– Incubation studies show FOS to be as cariogenic as sucrose, being rapidly metabolized following incubation with several strains of oral streptococci and inducing plaque growth

– Human plaque pH studies support these observations indicating FOS to be as acidogenic as sucrose and thus potentially cariogenic.

Fruit and dental caries

Health reports throughout the world encourage increased consumption of fruits and vegetables with a minimum intake quoted as 400 g per day or five portions. The 1989 UK COMA report recommended that in order to reduce the risk of dental caries, consumption of non-milk extrinsic sugars should be decreased and that these sugars should be replaced by fresh fruit, vegetables, and starchy foods. The UK National Food Guide “The Balance of Good Health” recommends that one-third of dietary volume should be provided by fruits and vegetables (fresh, canned, and frozen). Fresh fruit juices are included amongst fruit and vegetables, but it is

recommended that fruit juice consumption may count as only one of the minimum five portions. The preference towards whole fruits and vegetables is because these contain more non-starch polysaccharides and plant cell wall materials that benefit health. From a dental point of view, it is also preferable to consume whole fresh fruit as opposed to juices, because their mastication provides a good stimulus to salivary flow. In addition, fresh fruit juices contain non-milk extrinsic sugars, since liquidation releases the fruit sugars from the cellular structure of the fruit.

Human observational studies

There is little evidence from epidemiological studies in humans that consumption of fruit is associated with the development of caries; and indeed, negative correlations between fruit consumption and dental caries have been reported.

Dried fruit, potentially, may be more cariogenic; since the drying process breaks down the cellular structure of the fruit releasing extrinsic sugars. However, consumption of dried fruit is generally low and there are no epidemiological data to link it to caries development.

In two ***human intervention studies*** caries increment was low. Neither of these studies found that providing extra fruit in the form of apples increased caries levels.

Animal studies. Higher caries scores have been found in rats fed figs, apples, bananas, grapes, and raisins compared with rats fed citrus fruits, peanuts, or dried apricots. However, all fruits consumed resulted in lower caries prevalence than sucrose consumption alone. Animal studies have shown that when fruit is consumed very frequently (e.g. 17 times a day) it may induce caries, but less than sucrose. However, there are limitations in extrapolating the findings of these studies to humans.

Plaque pH studies. A number of plaque pH studies have found fruit to be acidogenic (but less than sucrose) although the extent of this varies according to texture and content of sugars.

Plaque pH studies have shown apples to depress pH to below 4.5. Bananas have been shown to depress pH to below 4 and to remain low for at least 90 minutes. Dates and raisins have been found to result in a low pH for a long period of time, while dried apple or apricot led to small changes in pH. However, when cheese is consumed 5 minutes after a sugar rinse, the sharp increase in acidity is blunted and the pH returns quickly to baseline. It is important to note that plaque pH studies measure acidogenic potential and do not account protective factors that are present in fruit or the stimulation to saliva flow from their consumption.

Incubation experiments have been used to give food products a decalcification score. In a study that tested 96 foods relative to sucrose at a score of 231, apple gave the lowest score of 4, pineapple 22, peach 48, pear 130, banana 180, and date 505. Vegetables gave very low scores. When foods are mixed with saliva and powdered enamel, bananas cause slightly less demineralization than sucrose, apples cause slightly more demineralization, and raisins cause twice as much demineralization as sucrose. Surprisingly, dates only cause around one-third of the de-

mineralization caused by sucrose. In experimental conditions, with fruit as a major dietary constituent, fruits may cause caries. However, if consumed as a part of the mixed human diet there is little evidence to show fruit to be an important factor in the development of dental caries. Furthermore, it is probably not possible to develop a valid cariogenic index for individual foods, since studies of caries incidence comparing groups consuming and not consuming various food items show little effect due to the strong cariogenic challenge from the rest of the diet.

FACTORS IN THE DIET THAT PROTECT AGAINST DENTAL CARIES AND EROSION

Foods and food components that have anti-cariogenic properties are sometimes referred to as "cariostatic factors". Fluoride is undoubtedly the most effective of these factors. However, dairy products, plant foods, tea, and even chocolate contain factors that protect against decay. Below is an overview of protective factors and the implications of their consumption for dental health.

Milk

Despite being one of the main sources of sugars in the diet of small children, normal milk consumption does not cause dental caries; and an inverse relationship between the consumption of milk and caries increment has been reported. Cow's milk contains lactose, which is less acidogenic than other mono and disaccharides, and it also contains calcium, phosphorus, and casein, all of which are cariostatic. Several studies have shown that the fall in plaque pH following milk consumption is negligible. A plaque pH study in human volunteers that compared the acidogenic potential of cow's milk and human breast milk with 7 % solutions of lactose and sucrose showed that sucrose caused a substantial decrease in plaque pH while both milks depressed pH only slightly and lactose decreased pH to a much lesser extent than sucrose (fig. 11).

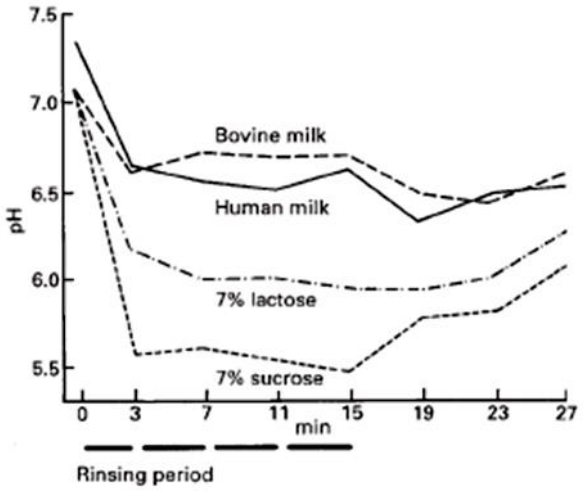


Fig. 11. Mean Stephan curves (relation between plaque pH and time) for 14 volunteer subjects who rinsed with cow's milk (bovine) human milk, 7 % lactose or 7 % sucrose four times during 15 minutes

There is some evidence from animal studies that the addition of milk to a cariogenic diet reduces the caries prevalence. Milk can be used safely by patients with low salivary flow as a saliva substitute. There have been a few reports of cases of severe dental caries associated with prolonged (usually over 2 years), on-demand breast feeding, often with infants feeding during the night when protection from saliva is low. However, these cases are rare and associated with unusual feeding practice. Therefore, human breast milk has a greater potential than cow's milk to cause dental caries but dental caries in human infants due to breast feeding is rare and is always associated with prolonged, on-demand feeding. As formula feeds contain similar amounts of lactose, calcium, and phosphate to breast milk, there are no benefits to dental health of feeding a formula feed. Breast feeding should be promoted since it provides the best infant nutrition.

Cheese

Numerous animal studies and experimental studies have indicated that cheese is anticariogenic. Plaque pH studies have shown that consuming cheese following a sugary snack virtually abolishes the usual fall in pH that is associated with sugars consumption. Cheese stimulates salivary secretion and increases plaque calcium concentration. The calcium concentration within dental plaque strongly influences the balance between de- and re-mineralization of enamel. Enamel slab experiments have shown that cheese promotes the remineralization of previously demineralized enamel and, in an epidemiological study, cheese intake was higher in children who remained caries-free over a two-year period than in those who developed caries (Rugg-Gunn et al. 1984). Furthermore, a controlled clinical trial showed that fewer caries developed over a two-year period in children who ate a 5g piece of hard cheese daily, following breakfast, compared with a control group who did not consume the extra cheese.

Studies of dietary composition in rats indicate that addition of certain cheeses (e.g., cheddar cheese) to a cariogenic diet protects against buccal (cheek side) decay both alone and with sulcal caries (toward the linear depression in the occlusal surface of the tooth).

Plant foods

A lower-than-expected caries level in groups of people known to have high carbohydrate diets — such as the Bantu Tribe of South Africa and sugar cane cutters, led to an interest in the presence of protective factors in foods of plant origin. The effects, on caries, of factors in foods of plant origin including organic phosphates, inorganic phosphates, and phytate have been investigated. It has been postulated that organic phosphates protect the teeth by adsorbing onto the enamel, forming a protective coat. Both organic and inorganic phosphates have been found to be effective in animal studies, but studies in humans have produced inconclusive results. Calcium sucrose phosphate was marketed as a cariostatic food additive in Australia, but its use was never supported by evidence from clinical trials. There are some questions and negative effects during consumption of phytate and inorganic phosphate.

Probably, one of the main reasons why people who consume diets high in unrefined plant foods have fewer carious lesions is due to stimulation of saliva flow that occurs on consumption of fibrous foods. Saliva not only helps to clear food debris from the mouth, but also buffers plaque acid, and therefore, favours remineralization of tooth enamel. Other foods that markedly increase saliva flow include chewing gum (sugar free), cheese, and peanuts.

Do chocolate and liquorice protect against dental caries?

In the Vipeholm study mentioned previously, the group receiving chocolate developed relatively fewer carious lesions than groups receiving similar amounts of sugars at similar frequencies. This led to the suggestion that chocolate contained protective factors. Animal studies also showed that cocoa may have a protective effect. In 1986 cocoa factor was extracted from chocolate and was shown to be effective in vitro. Recent studies have shown that theobromide in chocolate is able to increase crystal size in enamel, thus increasing the resistance to acid demineralization. In addition to "cocoa factor" and theobromide, milk chocolate contains calcium and casein, and is high in fat, which aids oral clearance. However, the high sugar content of chocolate outweighs these potential benefits. Likewise, honey contains protective esters, the benefit of which is outweighed by its high sugars content.

Glycyrrhizinic acid, a major constituent of liquorice, has cariostatic properties. Glycyrrhizinic acid inhibits bacterial glycolysis preventing the formation of acid from dietary sugars, and it increases the buffering potential of plaque. However, it has a strong taste, may cause staining of the teeth and liquorice may also cause electrolyte disturbances. Its use as an anti-caries factor is therefore somewhat limited.

Experimental clinical studies have shown that consumption of, or rinsing with, acidic beverages significantly lowers the pH of the oral fluids and this is most marked with grapefruit juice. Enamel slab experiments have shown that enamel is softened within 1 hr of exposure to cola but this may be reversed by exposure to milk or cheese.

Cocoa also contains substances that inhibit oral acidification. Starchy fibrous foods require increased mastication and may inhibit cariogenesis by stimulating saliva and maintaining neutral plaque pH. Studies suggest that polyols (sugar alcohols, including the 6-carbon sorbitol and 5-carbon xylitol) are noncariogenic and possibly even anticariogenic. Sorbitol-containing chewing gum, unlike sugar-containing gum, does not appear to promote tooth decay in children (Glass, 1983). Also, as noted earlier, the group on the xylitol diet in the University of Turku study had no DMFS. That finding was attributed to the fact that xylitol is not metabolized by oral microbes.

NON-SUGAR SWEETENERS

Sugar substitutes can be separated into two major groups intense sweeteners (non-caloric), and ”bulk sweeteners” (caloric). Some of these are naturally occurring compounds; however, the production of synthesized sweeteners has increased steadily due to new technologies and increased demand for sugars-free alternatives. The sweeteners that are permitted for food use varies between countries. Those permitted in the UK are listed in table 5.

Table 5

Bulk and intense non-sugars sweeteners permitted for food use in the United Kingdom

Sweetener	Food uses	Sweeteness (x sucrose)	Cariogenicity	Clinical trials	Disadvantages
Bulk					
Isomalt	Chocolate	0.5	Virtually non-cariogenic	No	Excess causes diarrhoea
Lycasin	Confectionery, gums	0.7	Between sorbitol and xylitol	Yes (sweets)	
Maltitol	Chewing gums	0.7	Virtually non-cariogenic	No	Excess causes diarrhoea
Mannitol	Dusting powder on chewing gums	0.7	Virtually non-cariogenic	One	Excess causes diarrhoea
Sorbitol	Confectionery, gums, jams	0.5	Virtually non-cariogenic	Yes (gums, sweets)	Excess causes diarrhoea
Xylitol	Mints, gums, confectionery	1.0	Non-cariogenic. Anticariogenic?	Yes (foods, gums, sweets)	Excess causes diarrhoea
Intense					
Acesulfame potassium	Low calorie drinks, confectionery and preserves	130	Non-cariogenic	No	
Aspartame	Soft drinks, dried and frozen foods, chewing gums	200	Non-cariogenic	No	Cannot be used by those with phenylketonuria
Saccharin	Table top sweeteners, drinks	500	Anticariogenic?	No	Bitter aftertaste
Thaumatin	With other sweeteners in soft drinks	3000	Non-cariogenic	No	Liquorice aftertaste

Intense sweeteners

Intense sweeteners are used in food products like soft drinks, beer, confectionery, desserts, ice cream, marmalade, and jam. They are also used in dentifrices and in sweetening drops/tablets for use in food, coffee, tea, etc. Currently, about 30 % of the carbonated beverages consumed in the USA are sweetened with the intense sweetener aspartame. Saccharin had been used in foods in the UK for almost a century. It has a bitter taste in concentrations over 0.1 %, although the perception of this varies between individuals. Saccharin is widely used in foods such as sweetening tablets. Acesulfame potassium is a chemically synthesized sweetener that is stable over a range of pH values and does not break down on heating. These properties make it a useful sweetener in boiled sweets and preserves. Aspartame is a dipeptide comprising of aspartic acid and phenylalanine. It is marketed under the brand names of “Nutrasweet” and “Canderel”. It is used extensively in frozen foods, desserts, drinks, and gums. Thaumatin, a protein extracted from a plant in West Africa is an example of a naturally occurring intense sweetener. It has a liquorice aftertaste and its main use is in pharmaceutical products. Food labels must declare if a product contains a sweetener and, in the case of aspartame,

the label must also say that the product contains a source of phenylalanine, because individuals with phenylketonuria are unable to metabolize this amino acid. Intense sweeteners are not metabolized to acids by oral micro-organisms and they cannot cause dental caries. Saccharin has been reported to inhibit bacterial growth and metabolism, but animal studies have shown that its caries-inhibiting effects are small. Limitations of intense sweeteners include poor taste quality, instability, and lack of volume. Caution is still needed when recommending products containing intense sweeteners because other ingredients, e.g. citric or phosphoric acids, in beverages may cause dental erosion. In some food products, intense sweeteners are added in addition to sugars, e.g. to fruit flavoured soft drinks, and the naturally occurring sugars in the drink (fructose, glucose, and sucrose) may also cause caries.

Bulk sweeteners

Bulk sweeteners provide sweetness and bulk to a food product. Many are sugar alcohols; and, being chemically similar to sugars, their cariogenicity has been tested in many types of experiments and, in some cases in clinical trials. Bulk sweeteners are widely used in confectionery, preserves and sugar-free gums. One of the disadvantages of the bulk sweeteners is that they are only partially absorbed in the small intestine and pass to the colon where they may induce osmotic diarrhoea. Bulk sweeteners are therefore not recommended for children under three years of age and care must be taken with sugar-free medicines containing bulk sweeteners, since high intakes cause gastrointestinal disturbance.

Field studies on xylitol, carried out in Russia, Hungary, and Estonia, have shown that xylitol is noncariogenic. Moreover, four clinical trials of xylitol in chewing gum have been conducted, namely, Turku chewing-gum study, the Ylivieska study, the Montreal study, and, most recently, the Belize study. All these studies have shown that the use of xylitol helps in the prevention of dental caries. Beside these four chewing-gum studies there is also clinical evidence that xylitol candies are as effective as xylitol gum in caries prevention and that it is economically feasible to include xylitol in school-based caries control programs. The Belize study is the first clinical trial of xylitol that enables the caries-preventive action of xylitol to be compared with sorbitol, and the results indicate that xylitol is superior in reducing caries. These findings should now be validated in randomized studies that account for dietary habits, oral hygiene practice, and socioeconomic status in other populations. Despite the promising findings, there is at present no strong evidence from clinical studies of a superior cariostatic action of xylitol compared with other polyalcohols.

The non-acidogenicity of mannitol is illustrated in figure 12.

1989 COMA report “Dietary Sugars and Human Disease” that concluded current evidence suggests that bulk sweeteners have negligible cariogenicity compared with sugars and that substitution of sugars by 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.

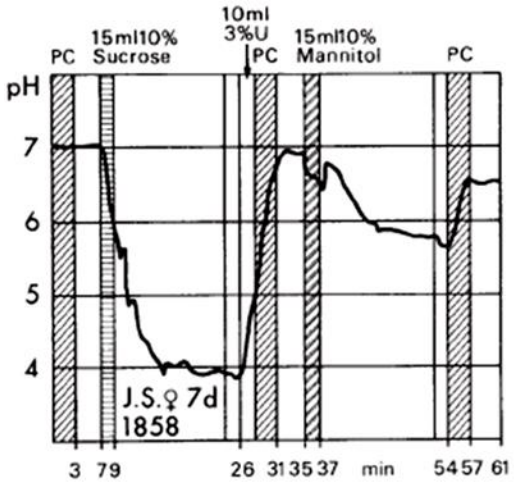


Fig. 12. Telemetrically recorded plaque pH after rinsing with (a) 15 ml of 10 % sucrose solution, (b) 15 ml of 10% mannitol solution. (Reproduced from Imfeld 1997, with permission of the editor of Helvetica Odontologica Acta.)

Features of non-sugar sweeteners are:

– The bulk sweeteners sorbitol, mannitol, lactitol, isomalt, lycasin, and maltitol are non-cariogenic or virtually so.

– Xylitol and the intense sweeteners are non-cariogenic.

– Chewing gums sweetened with xylitol and/or sorbitol protect against dental caries. This effect is due to the non-cariogenicity of the sweeteners and the stimulation of saliva flow resulting from chewing.

– It is important to remember that the usefulness of a sugar substitutes has to be looked upon not only from a cariological, but also from a nutritional, toxicological, economic, and technical point of view.

RELATIONSHIP BETWEEN DENTAL CARIES LEVELS AND SUGARS

There is evidence that the relationship between dental caries levels and sugars is an S-shaped relationship (fig. 13). At low levels of sugar intake (10 kg/person/year) caries is very low. At levels of intake around 15 kg/person/year, the line of the graph steeply rises and the level of caries increases with increasing sugar availability. At high levels of sugar intake (~35 kg/person/year) the curve flattens out and a saturation level is reached, so that a further increase in sugars content of the diet does not increase caries to an appreciable extent. The evidence for the sigmoid relationship between sugars intake and dental caries comes from a number of studies.

Data from Britain and Norway during the war years also support these findings. When Norwegian children consumed less than 10.4 kg/person/year, levels of dental caries were low. Children evacuated from Jersey during the war years were exposed to high intakes of sugar (30 kg/person/year) than those that remained in Jersey. Children in Jersey consumed sugar on average 8.3 kg/person/year and had a DMFT of 1.8 compared to 5.5 in the evacuees.

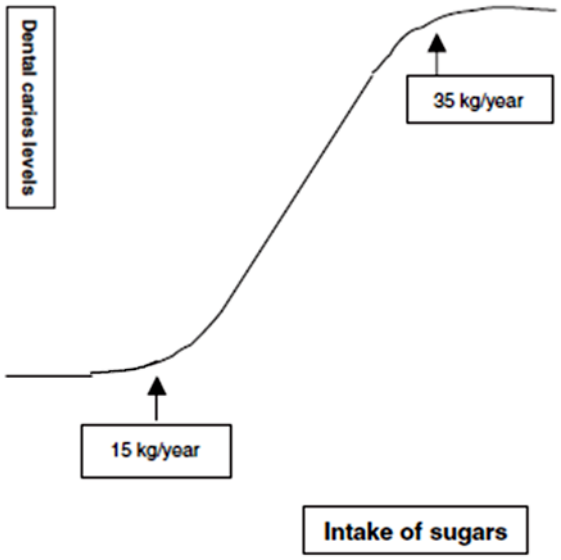


Fig. 13. Sigmoid curve to illustrate the relationship between intake of sugars and dental caries levels. Figures are based on data from epidemiological studies

The aforementioned data of Sreebny (1982) found that low caries rates were associated with low sugar intake in 12-year-old children; for the 21/47 countries where sugars availability was less that 18.25 kg/year (~50 g/day), DMFT levels were below 3.0, suggesting that this may be the upper safe limit for sugars intake. In Japan, caries levels increased as sugar intake increased through the years until a peak in sugar intake was reached at 29 kg/person/year in 1973. Thereafter, the intake of sugar decreased and so did the caries experience. The correlation between sugar availability and caries levels was high and significant (r=+0.91).

However, findings of other studies indicate that the correlation between sugar intake and caries occurrence is not entirely consistent. For example, caries incidence in Great Britain did not change appreciably from 1940 to 1977, despite an apparent doubling of sugar intake (Jackson, 1979). Likewise, the 32 % decline in caries prevalence in the United States in the 1970s appears to have occurred despite a continued high intake of sugars. A similar observation was made in Massachusetts schoolchildren, whose caries incidence dropped markedly during a period in which total sugar consumption increased and then leveled out. Although total sugar consumption increased during the study period, however, the amount of sucrose consumed actually decreased.

The decline in caries prevalence in the United States since the 1970s, despite a continued high consumption of total sugars, may be partially due to the nation's increasing consumption of corn-derived sweeteners such as fructose and the declining use of sucrose (Glinsmann et al., 1986).

The above studies were on populations not exposed to the benefits of fluoride.

Fluoride undoubtedly protects against dental caries, reducing caries in children by up to 50 %, but it does not eliminate it or remove the cause — sugars. In addition, the people of many parts of the world are not exposed to fluoride. A relationship between intake of sugars and caries still exists in the presence of adequate fluoride. Exposure to fluoride coupled with a reduction in the intake of sugars has

been shown to have an additive effect on caries reduction. A recent methodical literature review that investigated the importance of intake of sugars in populations exposed to fluoride concluded that where there is adequate exposure to fluoride, consumption of sugars remains a moderate risk factor for caries in most people.

Exposure to fluoride in some countries has altered the sugars–caries relationship. It has been argued that where fluoride is present in drinking water at a concentration of 0.7–1ppm, or over 90 % of toothpastes available are fluoridated, the dose–effect curve shifts to the right and raises the safe limit on the level of sugars consumption.

Sheiham argues that where fluoride in drinking-water is at 0.7–1 ppm, or where over 90 % of toothpastes available are fluoridated, the sugars caries relationship shifts and increases the safe level of sugars consumption from 10 kg/person/yr to 15 kg/person/yr. Exposure to fluoride alone may not eliminate caries but, along with reduction in free sugars intake, it has a significant effect on caries prevention. Research into effective means of delivering optimum exposure to fluoride should continue.

RECOMMENDATIONS FOR SUGAR INTAKE IN DIFFERENT COUNTRIES

A number of countries have adopted recommendations for sugars intake based on these data (table 6). In the UK, where there is widespread exposure to fluoridated toothpaste, the Dietary Reference Value for non-milk extrinsic sugars is 60 g/day or <10 % of energy intake. Similar recommendations have been adopted by several countries including the Scandinavian countries, the Netherlands, and Poland. The 1990 WHO report "Diet, Nutrition & Prevention of Chronic Diseases" also recommended that free sugars should contribute no more than 10 % to energy intake.

Table 6

Recommendations for intake of free sugars by a number of countries

Year	Country	Recommendation
1986	Netherlands, Ministry of Health	0–10 %
1987	Australia, Department of Health	≤ 12 %
1987	Finland, Nutrition Board	≤ 10 %
1989	Poland, National Institute	< 10 %
1990	WHO	< 10 %
1991	United Kingdom, Department of Health	≤ 10 %
1996	Nordic Nutrition Recommendations	≤ 10 %
1997	Sweden	≤ 10 %

RECOMMENDATIONS

General recommendations. It is important that there is a recommended maximum level for consumption of free sugars because when consumption of free sugars by a population is less than 15 kg/person/year levels of dental caries are

low. Population goals enable the health risks of populations to be assessed and progress in achieving health-promotion goals to be monitored.

Many countries that are currently undergoing nutrition transition do not have adequate exposure to fluoride and increasing intake of free sugars by these populations could have a severe impact upon the burden of disease. Promotion of adequate exposure to fluoride is important. To minimize dental erosion, the intake of acidic soft drinks should be limited.

The elimination of malnutrition will help to prevent and control developmental defects of the enamel, oral infectious diseases and periodontal disease and may delay the manifestation of the oral symptoms of HIV.

In line with the dietary goals for the prevention of all major diet-related chronic diseases, a diet that is high in fruits, vegetables and wholegrain starchy foods and low in free sugars and fat is likely to benefit many aspects of oral health including prevention of caries, periodontal conditions, oral infectious diseases and oral cancer.

Quantitative analyses show a log-linear dose-response relationship between the sucrose or its monosaccharide intakes and the progressive lifelong development of caries. This results in a substantial dental health burden throughout life. Processed starches have cariogenic potential when accompanying sucrose, but human studies do not provide unequivocal data of their cariogenicity. The long-standing failure to identify the need for drastic national reductions in sugars intakes reflects scientific confusion partly induced by pressure from major industrial sugar interests.

Recommendations for prevention of dental caries:

– In the presence of adequate exposure to fluoride, the intake of free sugars should be limited to 15 kg/person/year (equivalent to 40–55 g/day). In the absence of fluoride, the intake of free sugars should be below 15 kg/person/year (< 40 g/day). These values equate to 6–10 % of energy intake. The frequency of intake of foods containing free sugars should be limited to a maximum of four times a day.

– The potential financial consequence of failing to prevent dental caries needs to be highlighted, especially to governments of countries that currently have low levels of disease, but are undergoing nutrition transition (adopting a westernized diet).

– The detrimental impact on quality of life throughout the life course — the longer-term nutritional consequences of dental caries and tooth loss — need to be highlighted.

– The myth that a high sugars intake is important for energy intake and growth needs to be dispelled, especially in developing countries where undernutrition is prevalent.

– Restricting the intake of free sugars to 10 % of energy intake would still enable a sustained production of sugar cane as a cash crop in low-income countries.

– Regular monitoring of the prevalence and severity of dental caries should be encouraged using World Health Organization global guidelines, in different countries in all age groups.

– More national information on the dietary intake of sugars, sugar availability, and soft drink intake should be collected.

– Governments should support research into prevention of dental caries through dietary means.

– Nutrition needs to be recognized as an essential part of training for dental health professionals, and dental health issues, an important component of education of nutritionist and other health professionals. This is essential if advice for dental health is to be consistent with dietary advice for general health.

– Departments of Education must ensure that teachers, pupils, and health professionals receive adequate education on diet and dental health issues. There should be cross- Departmental guidelines for the use and content of educational materials to ensure they are sound, and not biased towards the interests of the food industry.

– International non-govermental organizations (e.g. World Health Organization, Food & Agricultural Organization, FDI, International Association for Dental Research) should recommend fiscal pricing policies for food items that are high in non-milk extrinsic sugars (free sugars) and are otherwise of questionable nutritional value, and should encourage governments to adopt more stringent codes of advertising practice, especially those aimed at children.

– Food manufacturers should continue to develop and produce low sugars/sugars-free alternatives to products rich in free sugars, including drinks. To enable individuals to make informed choices regarding sugars intake, there is a need for clear, unbiased, and non-misleading labelling of foods with respect to sugars contents.

Healthy Diet recomendations of WHO

A healthy diet helps to protect against malnutrition in all its forms, as well as noncommunicable diseases (NCDs), including such as diabetes, heart disease, stroke and cancer.

Unhealthy diet and lack of physical activity are leading global risks to health.

Healthy dietary practices start early in life — breastfeeding fosters healthy growth and improves cognitive development, and may have longer term health benefits such as reducing the risk of becoming overweight or obese and developing NCDs later in life.

Energy intake (calories) should be in balance with energy expenditure. To avoid unhealthy weight gain, total fat should not exceed 30 % of total energy intake. Intake of saturated fats should be less than 10 % of total energy intake, and intake of trans-fats less than 1 % of total energy intake, with a shift in fat consumption away from saturated fats and trans-fats to unsaturated fats, and towards the goal of eliminating industrially-produced trans-fats.

Limiting intake of free sugars to less than 10 % of total energy intake is part of a healthy diet. A further reduction to less than 5 % of total energy intake is suggested for additional health benefits.

Keeping salt intake to less than 5 g per day (equivalent to sodium intake of less than 2 g per day) helps to prevent hypertension, and reduces the risk of heart disease and stroke in the adult population.

WHO Member States have agreed to reduce the global population's intake of salt by 30 % by 2025; they have also agreed to halt the rise in diabetes and obesity in adults and adolescents as well as in childhood overweight by 2025.

For adults

A healthy diet includes the following:

Fruit, vegetables, legumes (e.g. lentils and beans), nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat and brown rice).

At least 400 g (i.e. five portions) of fruit and vegetables per day, excluding potatoes, sweet potatoes, cassava and other starchy roots.

Less than 10 % of total energy intake from free sugars, which is equivalent to 50 g (or about 12 level teaspoons) for a person of healthy body weight consuming about 2000 calories per day, but ideally is less than 5 % of total energy intake for additional health benefits. Free sugars are all sugars added to foods or drinks by the manufacturer, cook or consumer, as well as sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.

Less than 30 % of total energy intake from fats. Unsaturated fats (found in fish, avocado and nuts, and in sunflower, soybean, canola and olive oils) are preferable to saturated fats (found in fatty meat, butter, palm and coconut oil, cream, cheese, ghee and lard) and trans-fats of all kinds, including both industrially-produced trans-fats (found in baked and fried foods, and pre-packaged snacks and foods, such as frozen pizza, pies, cookies, biscuits, wafers, and cooking oils and spreads) and ruminant trans-fats (found in meat and dairy foods from ruminant animals, such as cows, sheep, goats and camels). It is suggested that the intake of saturated fats be reduced to less than 10 % of total energy intake and trans-fats to less than 1 % of total energy intake. In particular, industrially-produced trans-fats are not part of a healthy diet and should be avoided.

Less than 5 g of salt (equivalent to about one teaspoon) per day should be used. Salt should be iodized.

For infants and young children

In the first 2 years of a child's life, optimal nutrition fosters healthy growth and improves cognitive development. It also reduces the risk of becoming overweight or obese and developing NCDs later in life.

Advice on a healthy diet for infants and children is similar to that for adults, but the following elements are also important:

Infants should be breastfed exclusively during the first 6 months of life.

Infants should be breastfed continuously until 2 years of age and beyond.

From 6 months of age, breast milk should be complemented with a variety of adequate, safe and nutrient-dense foods. Salt and sugars should not be added to complementary foods.

Practical advice on maintaining a healthy diet

Fruit and vegetables

Eating at least 400 g, or five portions, of fruit and vegetables per day reduces the risk of NCDs and helps to ensure an adequate daily intake of dietary fibre.

Fruit and vegetable intake can be improved by:

– always including vegetables in meals;
– eating fresh fruit and raw vegetables as snacks;
– eating fresh fruit and vegetables that are in season; and
– eating a variety of fruit and vegetables.

Fats

Reducing the amount of total fat intake to less than 30 % of total energy intake helps to prevent unhealthy weight gain in the adult population. Also, the risk of developing NCDs is lowered by:

reducing saturated fats to less than 10 % of total energy intake;

reducing trans-fats to less than 1 % of total energy intake; and

replacing both saturated fats and trans-fats with unsaturated fats — in particular, with polyunsaturated fats.

Fat intake, especially saturated fat and industrially-produced trans-fat intake, *can be reduced by:*

– steaming or boiling instead of frying when cooking;
– replacing butter, lard and ghee with oils rich in polyunsaturated fats, such as soybean, canola (rapeseed), corn, safflower and sunflower oils;
– eating reducedfat dairy foods and lean meats, or trimming visible fat from meat; and
– limiting the consumption of baked and fried foods, and pre-packaged snacks and foods (e.g. doughnuts, cakes, pies, cookies, biscuits and wafers) that contain industrially-produced trans-fats.

Salt, sodium and potassium

Most people consume too much sodium through salt (corresponding to consuming an average of 9–12 g of salt per day) and not enough potassium (less than 3.5 g). High sodium intake and insufficient potassium intake contribute to high blood pressure, which in turn increases the risk of heart disease and stroke.

Reducing salt intake to the recommended level of less than 5 g per day could prevent 1.7 million deaths each year.

People are often unaware of the amount of salt they consume. In many countries, most salt comes from processed foods (e.g. ready meals; processed meats such as bacon, ham and salami; cheese; and salty snacks) or from foods consumed frequently in large amounts (e.g. bread). Salt is also added to foods during cooking (e.g. bouillon, stock cubes, soy sauce and fish sauce) or at the point of consumption (e.g. table salt).

Salt intake can be reduced by:

– limiting the amount of salt and high-sodium condiments (e.g. soy sauce, fish sauce and bouillon) when cooking and preparing foods;

– not having salt or high-sodium sauces on the table;

– limiting the consumption of salty snacks; and

– choosing products with lower sodium content.

Some food manufacturers are reformulating recipes to reduce the sodium content of their products, and people should be encouraged to check nutrition labels to see how much sodium is in a product before purchasing or consuming it.

Potassium can mitigate the negative effects of elevated sodium consumption on blood pressure. Intake of potassium can be increased by consuming fresh fruit and vegetables.

Sugars

In both adults and children, the intake of free sugars should be reduced to less than 10 % of total energy intake. A reduction to less than 5 % of total energy intake would provide additional health benefits.

Consuming free sugars increases the risk of dental caries (tooth decay). Excess calories from foods and drinks high in free sugars also contribute to unhealthy weight gain, which can lead to overweight and obesity. Recent evidence also shows that free sugars influence blood pressure and serum lipids, and suggests that a reduction in free sugars intake reduces risk factors for cardiovascular diseases.

Sugars intake can be reduced by:

limiting the consumption of foods and drinks containing high amounts of sugars, such as sugary snacks, candies and sugar-sweetened beverages (i.e. all types of beverages containing free sugars — these include carbonated or non-carbonated soft drinks, fruit or vegetable juices and drinks, liquid and powder concentrates, flavoured water, energy and sports drinks, ready-to-drink tea, ready-to-drink coffee and flavoured milk drinks); and eating fresh fruit and raw vegetables as snacks instead of sugary snacks.

How to promote healthy diets

Diet evolves over time, being influenced by many social and economic factors that interact in a complex manner to shape individual dietary patterns. These factors include income, food prices (which will affect the availability and affordability of healthy foods), individual preferences and beliefs, cultural traditions, and geographical and environmental aspects (including climate change). Therefore, promoting a healthy food environment — including food systems that promote a diversified, balanced and healthy diet — requires the involvement of multiple sectors and stakeholders, including government, and the public and private sectors.

Governments have a central role in creating a healthy food environment that enables people to adopt and maintain healthy dietary practices. **Effective actions by policy-makers to create a healthy food environment include the following:**

– creating coherence in national policies and investment plans — including trade, food and agricultural policies – to promote a healthy diet and protect public health through:

– increasing incentives for producers and retailers to grow, use and sell fresh fruit and vegetables;

– reducing incentives for the food industry to continue or increase production of processed foods containing high levels of saturated fats, trans-fats, free sugars and salt/sodium;

– encouraging reformulation of food products to reduce the contents of saturated fats, trans-fats, free sugars and salt/sodium, with the goal of eliminating industrially-produced trans-fats;

– implementing the WHO recommendations on the marketing of foods and non-alcoholic beverages to children;

– establishing standards to foster healthy dietary practices through ensuring the availability of healthy, nutritious, safe and affordable foods in pre-schools, schools, other public institutions and the workplace;

– exploring regulatory and voluntary instruments (e.g. marketing regulations and nutrition labelling policies), and economic incentives or disincentives (e.g. taxation and subsidies) to promote a healthy diet; and

– encouraging transnational, national and local food services and catering outlets to improve the nutritional quality of their foods — ensuring the availability and affordability of healthy choices – and review portion sizes and pricing.

Encouraging consumer demand for healthy foods and meals through:

– promoting consumer awareness of a healthy diet;

– developing school policies and programmes that encourage children to adopt and maintain a healthy diet;

– educating children, adolescents and adults about nutrition and healthy dietary practices;

– encouraging culinary skills, including in children through schools;

– supporting point-of-sale information, including through nutrition labelling that ensures accurate, standardized and comprehensible information on nutrient contents in foods (in line with the Codex Alimentarius Commission guidelines), with the addition of front-of-pack labelling to facilitate consumer understanding; and

– providing nutrition and dietary counselling at primary health-care facilities.

Promoting appropriate infant and young child feeding practices through:

– implementing the International Code of Marketing of Breast-milk Substitutes and subsequent relevant World Health Assembly resolutions;

– implementing policies and practices to promote protection of working mothers; and

– promoting, protecting and supporting breastfeeding in health services and the community, including through the Baby-friendly Hospital Initiative.

Recommendations to international organizations for the prevention of dental diseases

The potential financial consequence of failing to prevent dental diseases need to be highlighted, especially to governments of countries that currently have low levels of disease but are undergoing nutrition transition. The detrimental impact of quality of life throughout the life course and the longer-term nutritional consequences of dental disease and tooth loss also need to be highlighted. The WHO should encourage and aid the regular monitoring of the prevalence and severity of dental disease (e.g. caries, erosion) in different age groups and the prevalence of tooth loss in different countries. The WHO and FAO should also aid the collection of national information on the amount and frequency of dietary free sugars and soft drink intake and should provide guidance to nations on standardised methods for data collection on appropriate study populations where necessary.

The WHO should promote efforts to address identification of suitable means of delivering optimum fluoride to countries where exposure is inadequate. The WHO and other international organisations should recognise nutrition as an essential part of training for dental health professionals, and dental health issues, an important component of the education of nutritionists and other health professionals. This is essential if advice for dental health is to be consistent with dietary advice for general health.

Recommendations to governments and intersectoral ministries

Governments should set strategies to implement the recommendations of the report of the joint WHO/FAO expert consultation on Diet and the prevention of chronic diseases and should support food-based dietary guidelines. Governments should establish the means of monitoring the severity and prevalence of oral diseases and the risk factors associated with them (e.g. free sugars intake) and should adopt global standard guidelines for methods of data collection where available. These data should be made available to the WHO to enable continuous updating of the WHO oral health database. Governments should support research into elucidating optimum fluoride intake by different age groups and effective means of delivering optimum fluoride and should also support research into nutrition and dental health relevant to countries' needs e.g. research into effective means of dietary intervention for dental health. Governments should ensure that teachers, pupils and health professionals receive adequate education on diet, nutrition and dental health issues. Governments should also provide guidelines for the use of and content of educational materials to ensure they are sound and nonbiased. Governments should set more stringent codes of practice on advertising (including advertising and information on the Internet) of sugars-rich items.

Recommendations to private sector and industry

Food manufacturers should continue to produce lowsugars/sugars-free alternatives to products rich in free sugars, including drinks. Manufacturers should also look at means to reduce the erosive potential of soft drinks. To enable individuals to make informed choices regarding the oral health/dental problems related to high and frequent free sugars intake, there is a need for clear and unbiased labelling of foods with respect to sugars contents.

Recommendations to civil society

Oral health education should be included in nutrition education at schools and at antenatal classes where available, and should be based on sound non-biased information. Oral health education should be promoted alongside other forms of health education and dietary and nutrition advice for oral health should be integrated with advice for general health. Health education campaigns and health promotion websites should be encouraged.

Recommendations at the level of the individual

Individuals should be recommended to reduce the frequency with which they consume foods containing free sugars to four times a day and thereby limit the amount of free sugars consumed. In countries where fluoride toothpaste is available/affordable, individuals should be encouraged to brush their teeth with a fluoride toothpaste twice a day.

Recommendations for communication of multiple partners

The measures needed require the actions of multiple partners: health care providers (pediatricians, other physicians, dentists, dietitians, and allied health professionals), local community leaders, legislators, government agencies, educators, the media, industry, and other concerned individuals and organizations. Programs to improve children's oral and general health include the following necessary elements:

1. Dietary counsel. Health professionals and others as appropriate need to counsel parents, other caretakers, and children to moderate sugar, salt, and fat intake to achieve adequate growth and development and adhere to high-quality diets, following dietary guidelines by using MyPyramid resources provided by the USDA. Education should include the role of frequency of consumption of sugary foods and beverages and why frequency can increase caries risk. Support for inclusion of nutrition education and skill development in health literacy for future medical and dental professionals and continuing education for practitioners can enhance these efforts. Registered dietitians can guide practices and provide consultation to health professionals and the public and develop skills in addressing the oral components of general health.

2. Advocacy. Health professionals and allies should organize, lead, and work with local community, state, and national organizations to improve access necessary for a healthful diet, including, for example, the promotion of legislation to provide incentives for establishing well-stocked supermarkets and grocery stores in poor neighborhoods.

3. Health professional training. Health professional training and continuing education should include skill development in diet promotion and counseling in support of oral and general health. Representation on local, regional, and state boards involved in improving environments that support healthy communities, schools, and families should be sought and leadership should be achieved.

4. Advice to expectant mothers. Educational protocols need to be established to advise pregnant women about healthy diets and provide guidance on infant feeding, emphasizing the value of breast feeding and the necessity of restricting nighttime bottle feeding to decrease caries risk.

5. Guidance on home eating patterns. Parents should be advised that they are role models able to set eating behaviors at home by providing high-quality meals and having fruits and vegetables and other healthy foods available as snacks. Advice should include discouraging frequent consumption of high-fat, high-sugar foods and the realization that acceptance of new foods may require repeated presentations of the food. Community resources to assist families in developing skills in purchasing and preparing healthy foods and meals should be included in patient education.

6. Cultural/ethnic sensitivity. Family demographics, cultural/ethnic practices, and food related environmental issues should be routinely taken into consideration to tailor education and counseling to the unique needs of a family.

7. Skilled health care providers. Multidisciplinary teams including dental professionals, pediatricians, nurses, registered dietitians, family practice physicians, and other allied health care professionals should be trained to screen, educate, and counsel children and families to access care and seek medical and dental homes with active health promotion programs that include diet, nutrition, and dental education resources. Awareness among primary care providers of the potential association between obesity and caries can lead to early interventions and improved health status for all children.

An ecological model identifiying factors influencing eating behaviours was proposed (fig. 14).

On 21–26 May 2012 the WHO approved Comprehensive implementation plan on maternal, infant and young child nutrition **WHA65/6**. The main targets are:

– 40 % reduction in the number of children under-5 who are stunted;
– 50 % reduction of anaemia in women of reproductive age;
– 30 % reduction in low birth weight;
– no increase in childhood overweight;
– increase the rate of exclusive breastfeeding in the first 6 months up to at least 50 %;
– reduce and maintain childhood wasting to less than 5 %.

ADA gave us simple and useful recommendations (1982):

– Maintain a balanced diet.
– Minimize the number of unnecessary snacks consumed each day.
– Restrict sweet consumption to meal time.

– Do not allow infants to sleep with bottles containing sweetened liquids, fruit juices, milk or formula.

– Brush and floss thoroughly each day to remove dental plaque.

– Use an ADA-accepted fluoride dentifrice and mouserinse. Consult your dentist about the need for supplemental fluorides.

– Visit a dentist regularly.

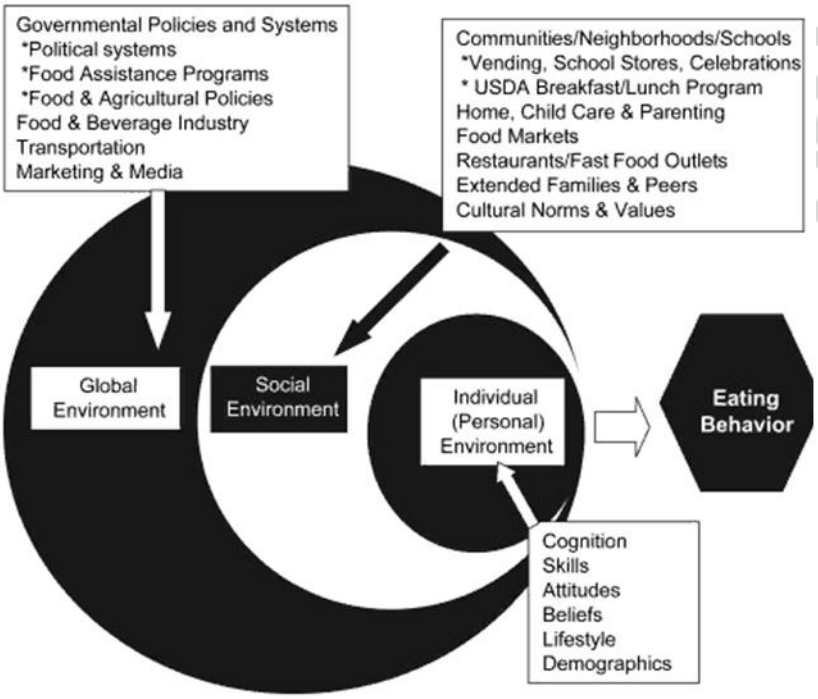


Fig. 14. An ecological model identifiying factors influencing eating behaviours. USDA indicates United States Department of Agriculture

MODIFICATION OF BEHAVIOUR TO REDUCE DENTAL CARIES

Statement on Diet and Dental Caries

It is important to help people to modify their behaviour to reduce their risk of developing dental caries.

The group identified seven areas of influence for promoting dietary behaviour modification. These topics are closely linked and interactive (fig. 15). However, for the sake of clarity they will be discussed separately:

(1) laws and regulations which should be enacted to benefit dental health within the wider context of general health;

(2) utilizing and modifying cultural norms and values to change dietary habits;

(3) ensuring adequate oral health education for the community as a whole;

(4) monitoring and improving the availability of non-cariogenic foods;

(5) assessing the needs of individuals in terms of their socio-economic status and education;

(6) forging closer links with the food industry to promote oral health in a co-operative manner;

(7) persuading the media in all their forms to consider the scientific basis of the dental health message, and more effective dissemination of information.

These seven spheres of interest will be modified by a number of different groups, therefore a model has been constructed to illustrate some of the problem areas (fig. 15). The model is an oversimplification of a series of complex interactions, but in this instance is being used to provide a simple framework to highlight some possible ways of influencing dietary behaviour.

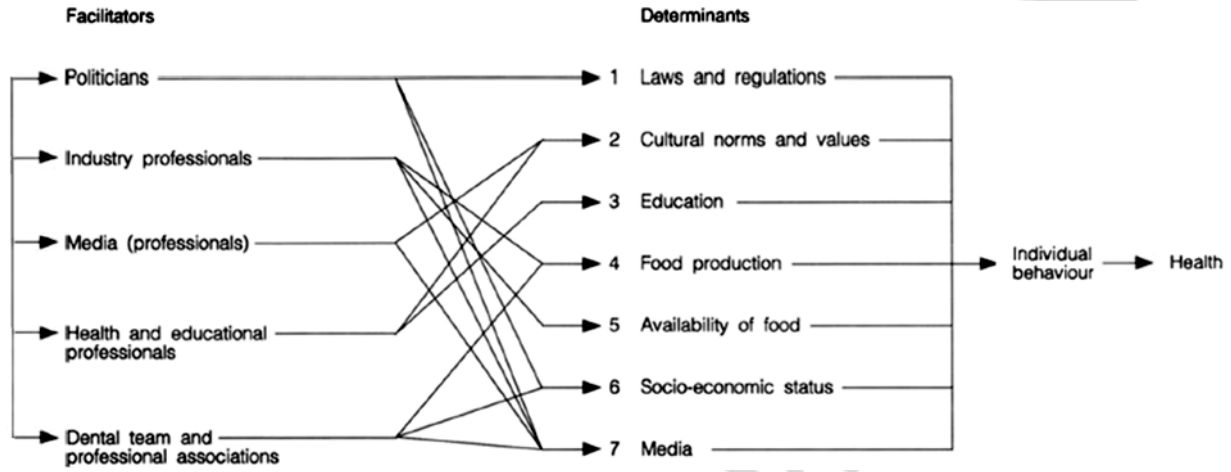


Fig. 15. Simplified model of the interactive relationship shaping dietary behaviour, education and policy decisions

(1) Laws and Regulations

Laws and regulations can influence dietary behaviour, for example regulations should be enacted to ensure that all children are given guidelines on nutrition whilst at school. Also more emphasis must be given to promoting sugar-free medicines, so as to avoid promoting frequent consumption of sugar. In some countries non-sugar sweeteners are not permitted and new regulations may be required. The model shows how laws and regulations can be influenced by the dental team advising politicians on oral health policy.

(2) Cultural Norms and Values

Dietary norms and values are greatly influenced in a general fashion by the media and in more specific areas by health and education professionals. Role models such as sports personalities and pop stars could be used to promote the value of an attractive smile. Primary socialization of particular value as behaviour is being shaped rather than changed, so a more positive approach to dietary education can be adopted.

(3) Education

Education is considered to be useful in behaviour modification. As envisaged in the model this will usually be undertaken by the health and education professionals. It should cover all people, but especially children who should be informed on how to make healthy dietary choices. It should be stressed that the dental teams require further education on diet and health. Nutrition should be included in the dental curriculum as a separate entity. Special nutritional teaching is im-

portant for spread of knowledge to the other groups mentioned in the model (e.g. teachers, health professionals) as well as to the general population.

(4) Food Production

We have recognized that there may be some problems in producing dentally safe foods and recommend that efforts should be made and research done so that these difficulties are minimized.

(5) Availability o f Food

The concept: make the healthier choice the easier choice, applies for oral health, as knowledge about dentally safer food is of no use if such food does not exist. This is obviously related to the decision makers in industry who should find it attractive to produce such food.

(6) Socio-Economic Status

Numerous studies have shown a close relationship between health behaviour and socio-economic status so further comments are unnecessary.

(7) Media

Efficient co-operation with the media by dental, education and health professionals is essential if the dietary messages are to be effectively disseminated. Further training in the use of journalistic techniques by designated dentists or journalists specialized in the field would be of value. It would also be helpful to provide information in a simple but scientifically valid format for use by the media.

Diet Assessment

Diet assessment in behaviour modification should be regarded as a teaching (reinforcing) tool and should therefore be easy to handle and easy to interpret; absolute reliability is of minor importance when discussing diet with individual patients. The group realized that there are some unsolved problems connected to assessing diet for scientific purposes but decided not to deal with this.

FOOD DIARY

There are several methodologies for the nutritional assessment method (table 7). It should be remembered that dentists can only assess the risk of caries and give general recommendations regarding the balance of the diet and specific suggestions on the multiplicity of meals and the choice of products for snacking.

Table 7

Method of nutrition assessment

Method	Use	Limitations	Advantages	Disadvantages
Food records Food diary Diet diary	Prospective Councelling Research	None	Accurate	Time-consuming Relies on patient's accuracy and truthfulness
24-hour recall	Population studies	Neither for young children nor for very old	Rapid, cheap 20 min	Underestimates sugar and alcohol intake

End of table 7

Method	Use	Limitations	Advantages	Disadvantages
Retrospective diet history	Diet consumed 10–20 years earlier	Not for patient groups with impaired memory	Excellent to study dietary aspects of chronic diseases	Underestimates sugar and alcohol Time-consuming

Diet diary. The food diary or diet diary is recorded during 3 or 7 consecutive days. From among the recorded days both weekdays and weekend days should be represented. Subjects asked to keep a diet diary need clear instructions how to record the quality and the amount of food consumption. Exact descriptions of the time, type, brand and preparation method of all foods and drinks are needed. The amount consumed is asked to be recorded using ordinary household measures like glasses, cups or tablespoons. Pictures of portions can be used for further assistance. The method is used for prospective purposes, and is the best method for dietary counselling. The method is suitable for scientific purposes, accurate (provided the patient records thoughtfully and accurately) and allows recording of nutrient intake at 10 % accuracy level. A disadvantage is that it is time consuming to record and analyse.

24-hour recall. The 24-hour recall is perhaps the most common. It records the diet of the previous day, and is suitable for population studies. The method is rapid, taking only about 20 minutes to record, and is therefore inexpensive. Unfortunately, it is inappropriate for very young or very old subjects and may underestimate the consumption of alcohol and sweets.

Diet history. Retrospective diet history is relatively seldom used since the method was developed to record diet 1−2 decades earlier. Diet history can be used for subjects up to old age. It gives reliable information about diet of regular meals and is suitable for dietary risk assessment of chronic diseases. However, the method is expensive as it needs about 60−90 minutes to record. Apart from patients with obvious memory dysfunctions, no age-related limitations are known to prevent the use of this method. Underestimation of sugar, fat and alcohol are the known disadvantages.

Food diary

Analysis of a food diary consists of several stages:

Stage 1. Identifying of foodstuffs belonging to a certain group: 1 — bread, 2 — milk, 3 — meat, 4 — fruits and vegetables, 5 — carbohydrate foods, including sweets should be done. Estimation of meals and snacks certain number, as well as the frequency of carbohydrate food consumption should be made. Take notes in the food diary (designation of group codes, to define the meals).

Stage 2. Drawing of table "Analysis of a food diary", the calculation of average values for each analyzed items, the determination of deviations of the estimated parameters from the norm. Building charts and graphs, using the form "Nutrition Specifications".

Stage 3. Making the conclusions and recommendations.

The findings indicate:

1) frequency of meals. Determine conformity of meals and snacks to standards. It was found that if the food is used not more than five times a day, the risk of caries disease is minimal;

2) frequency of sweet food consumption and carbohydrate containing foods. Estimate frequency of snacks with sweets, sugary drinks and cariogenic carbohydrate food;

3) balance of food. A balanced diet is achieved by regular use of four major product groups: bread, milk, meat and fruit and vegetables.

Variants of conclusion for individual, associated with the nutrition factor may be following:

– any caries risk factors related to diet have not been revealed;

– there is a small, easy to handle risk of caries associated with the nutrition factor;

– there is obvious significant risk of developing caries that linked to the nutrition factor;

– risk factors for caries are predominant and associated with nutrition factor;

Recommendations contain information on all items of conclusion. Possible recommendations:

– Keep the same diet.

– Keep the same diet, but balance the foods, by reducing the frequency of the use of one and increase the other (please specify which).

– You need a serious diet regimen correction: reduce the frequency of food intake less than 5 times a day, quantity of snacks less than 2 times a day, and you have to balance your diet.

Example №1

Conclusions from the nutrition diary:

1. The frequency of main meals and snacks is 4, which does not exceed the safety standards (no more than 5 times a day).

2. Consumption frequency of carbohydrate during meals is not more than 2 times a day, and sweet foods are used in meals.

3. Balance of nutrition: there are all food groups in recommended proportions.

Conclusion: The analysis of your food diary does not reveal any caries risk factors related to diet.

Recommendations: You are advised to keep the same diet.

Example №2

1. Frequency of meals is less than 3 times, but the frequency of snacks is 5. It exceeds the recommended frequency (2 times). The total number of meals is 8 (norm — 5).

2. Consumption frequency of carbohydrate containing food is 7, which is significantly higher than normal, and starchy food is taken mainly in snacks. It leads to a significant risk of tooth decay.

3. Nutrition is unbalanced due to the predominance of meat and bread products and insufficient consumption of dairy, fruit and vegetables.

Conclusion: The analysis of your food diary reveals obvious significant risk of developing caries linked to the nutrition factor.

Recommendations: You need a serious diet correction: reduction in the frequency of meals (basic and snacks) to 5 times a day, reducing the number of snacks to 2 times a day, and you have to balance your diet by reducing the consumption of meat and bread and increase the use of fruits, vegetables and dairy products.

Analysis of a nutrition diary of A. S. Ivanov _____25_____

(Name, Family name)

(age, years)

Period of checking from 01.09 to 08.09.2018 year.

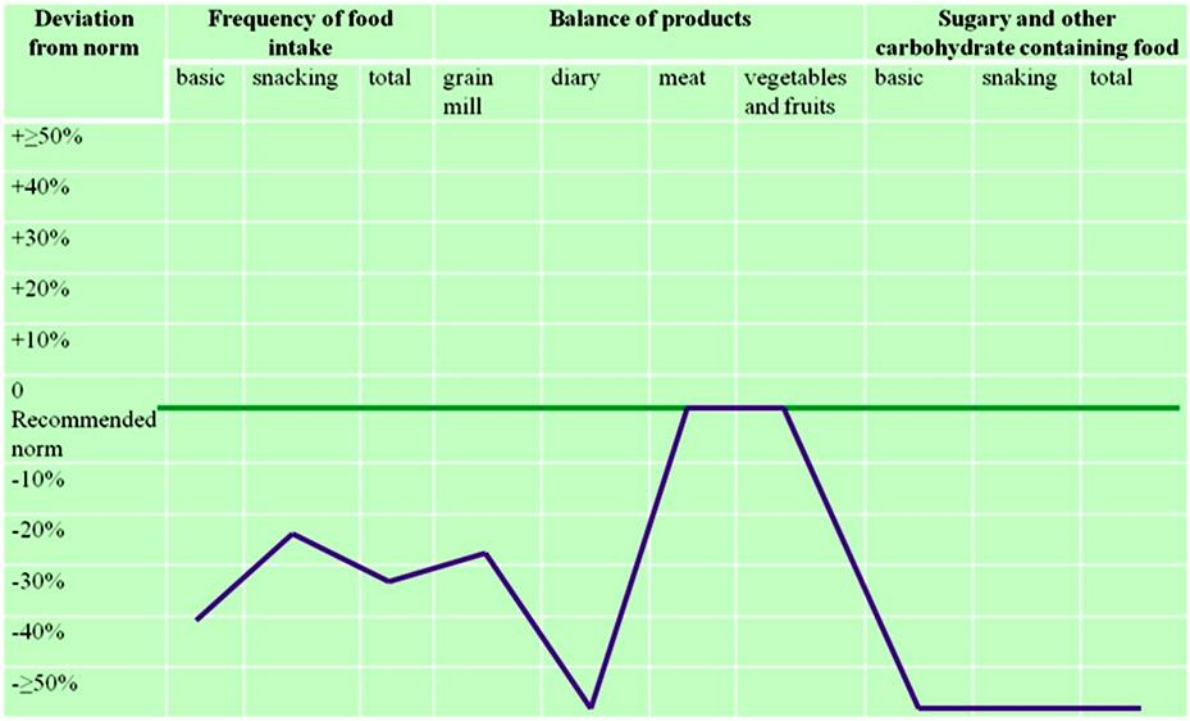
Meals	**Days diary**							**Average value per week Σ times 7 days**	**Recommended norms of healthy food (number of times)**			**Deviations from norma (in%)**
	1	**2**	**3**	**4**	**5**	**6**	**7**		**Children under 12 years**	**Teenagers 13–18 years**	**Adults from 19 years**	
The number of basic meals	2	1	2	3	1	2	3	2	3	3	3	-33
Snacking	1	2	2	2	1	2	2	1.7	2	2	2	-15
Total	3	3	4	5	2	4	5	5.7	5	5	5	-26
The use of basic food products grain mill	3	4	5	4	3	4	4	3.2	4+	4	4	-20
dairy	2	2	1	0	2	2	1	1.4	4	4	4	-65
meat	2	2	3	2	1	2	2	2	2	2	2	0
vegetables and fruits	3	4	5	4	3	5	4	4	4	4	4	0
Eating sugary and other carbohydrate containg foods during main meals	1	1	1	0	1	0	1	0.7	≤3	≤3	≤3	-76
while snacking	0	0	0	0	0	1	1	0.3	≤2	≤2	≤2	-86
Total	1	1	1	0	1	1	2	1	≤5	≤5	≤5	-80

Example of deviation from the norm calculation N/norma*100 % – 100 %

2/3*100 % – 100 %= - 33 %

6/3*100 % – 100 % = 100 %

Characteristics of nutrition. During checking period from 01.09 to 08.09.2017 year.



Legend:

0 — the zero line indicates the norm of nutrition parameters

+ — Increase (in % from normal) in the number of meals

- — Decrease (in % from normal) in the number of meals

Signature of doctor_____

Conclusions:

The frequency of meals and snacks is within normal limits (no more than 5 times a day).

Consumption frequency of carbohydrate during meal is not more than 3 times a day (0.7) and during snacks not more than 2 times a day (0.3), and sweet products is used in the meals.

Balance of nutrition. The frequency of bread and meat products consumption is below the norm (possibly increasing up to 4 times a day). The frequency of consumption of meat, fruit and vegetable products corresponds to the norm.

Summary: any caries risk factors related to diet have not been revealed. The mode of sweets consumption to leave the same or probably to increase their consumption up to 3 times during the meals and 2 times during snacks. Keep the same diet, but improve the balance — increase the frequency of consumption of bread and meat products up to 4 times a day.

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Учебно-методическое пособие

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