Dietary Determinants of Dental Caries and Dietary Recommendations for Preschool Children

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ABSTRACT

Objectives: The purpose of this review, commissioned by the Administration for Children and Families, the Health Resources and Services Administration, the Health Care Financing Administration, and the Department of Agriculture's Food and Nutrition Service, was to update the evidence of the dietary factors that affect dental caries, and subsequently formulate dietary recommendations for preschool children based on principles of cariology. **Methods:** Literature on the dental caries process, dietary factors affecting dental caries initiation and progression, nutrition education and counseling were reviewed and synthesized. Dietary guidelines for children at various ages were then constructed based on the review. **Results:** Dental caries in preschool children is due to a combination of factors, including colonization of teeth with cariogenic bacteria, type of foods and frequency of exposure of these foods to the cariogenic bacteria, and susceptible teeth. Caries risk is greatest if sugars are consumed at high frequency and are in a form that is retained in the mouth for long periods. Sucrose is the most cariogenic sugar because it can form glucan that enables firm bacterial adhesion to teeth and limits diffusion of acid and buffers in the plaque. There is emerging interest in the effects of tooth development and its role in the future dental caries risk of the child. **Conclusions:** Nutrition education and counseling for the purposes of reducing caries in children is aimed at teaching parents the importance of reducing high frequency exposures to obvious and hidden sugars. Guidelines include: avoiding frequent consumption of juice or other sugar containing drinks in bottle or sippy cup; discouraging the behavior of a child sleeping with a bottle; promoting non-cariogenic foods for snacks; fostering eating patterns consistent with Food Guide Pyramid; limiting cariogenic foods to mealtimes; rapidly clearing cariogenic foods from the child's oral cavity either by tooth brushing or by consumption of protective foods; and restricting sugar containing snacks that are slowly eaten (e.g., candy, cough drops, lollipops, suckers). Along with nutritional factors, a comprehensive approach to preventing dental caries in preschool children must include improved general dietary habits, good oral hygiene, appropriate use of fluorides, and access to preventive and restorative dental care.

The Dental Caries Process

The assertion that diet plays a central role in the development of dental caries is unquestionable. Observations in humans, in animals and in vitro have clearly shown that frequent and prolonged oral exposure to certain carbohydrates are fundamental to caries activity. The mechanism by which diet affects dental caries is rather simple. The bacteria attached to teeth, the so-called dental plaque, utilize mono and di-saccharides (e.g., glucose, fructose, sucrose) in their glycolytic pathways to produce energy, and acid is a byproduct of this metabolism. Consequently, the acidity of dental plaque may fall to a point where the demineralization of the tooth ensues. The rate of demineralization is dependent upon the absolute pH decrease, as well as the length of time that the pH is below a level that fosters dissolution of enamel. The "critical pH" value for demineralization varies among individuals, but is in the approximate range of 5.2 to 5.5 (1) (Fig. 1). Conversely, the pH of the environment adjacent to the tooth may be increased by: lack of substrate for bacterial metabolism, low percentage of cariogenic bacteria in the plaque, elevated secretion rate of saliva, strong buffering capacity of saliva, presence of inorganic ions in saliva and rapid food clearance times, all resulting in less bacterial acid production, or rapid acid clearance from the plaque.

If the pH of the environment at a specific tooth location remains below the critical level for sufficient time, enamel demineralization predominates and tooth mineral is lost. The initial stages of tooth loss occur just below the enamel surface to produce a visual whitening of the tooth, referred to as the "white spot lesion." At this stage of mineral loss, the lesion may not progress any further, or could even regain minerals (i.e., remineralize) if the cariogenic environment diminishes. Treating the tooth with fluoride, decreasing the carbohydrate source to the bacteria, reducing the levels of cariogenic bacteria, or lessening the ability of bacteria to produce acid are the preventive approaches that can remineralize the initial carious lesion. However, if disease suppression procedures are not initiated and the acidic challenge is unabated, the initial lesion will continue to lose mineral. The progressive dissolution of enamel and loss of enamel surface structure eventually give rise to a frank carious lesion (cavity). Carious lesions, even at this stage, can be successfully arrested from progression; however, such lesions often benefit from surgical and restorative procedures to replace the damaged dental tissue.

There is abundant evidence showing the predominate role in the carious process of only a few of the many bacteria that inhabit the oral cavity. One group of these microorganisms, the mutans streptococci (ms), is most associated with the dental caries process. Classic animal experiments by Fitzgerald and Keyes (2) showed that rats did not develop dental caries from sugar-rich diets unless they had been infected with these oral streptococci. More recent findings have

shown that pre-school children with high colonization levels of ms in their oral cavity have a much greater caries prevalence, as well as a much greater risk for new lesions than those children with low levels of ms (3). Ms are believed to be more caries conducive because of their ability to adhere to tooth surfaces, produce copious amounts of acid, and be able to survive and continue metabolism at low pH conditions (for review, see reference 4).

The colonization of a child's oral cavity with ms can occur only after the eruption of teeth because ms requires a non-shedding surface for attachment (5). Ms colonization of the oral cavity, starting as early as 10 months of age (6), is generally the result of transmission of these organisms from the child's primary care giver, usually the mother (7). The exact method of transmission is not known, but it is suspected to be due, in part, to sharing utensils and foods. It has been shown that the earlier a child is colonized with ms, the greater the risk for caries (8).

In contrast to the strong associations of ms with caries, the concept that lactobacilli are central to caries causation has generally fallen into disfavor. Because lactobacilli cannot adhere to smooth surface enamel, it is not possible for this organism to initiate a carious lesion; yet, lactobacilli are often isolated from deep dentinal carious lesions and are believed to play a role in the progression of lesions once initiated (9). Lactobacilli levels in saliva also increase in individuals at high caries risk, but this increase appears to reflect an increase of total carbohydrate consumption by individuals (10).

Dental caries in children should therefore be understood as a transmissible and infectious bacterial disease. Children first need to become colonized with ms before they are capable of caries activity. When these cariogenic bacteria have an environment that favors their proliferation and metabolism as a result of frequent exposure to carbohydrates, large quantities of acid can be generated adjacent to tooth surfaces. With frequent and repeated acid attacks, tooth demineralization will result in a white spot lesion that, if not reversed, will become a cavitated enamel lesion. If no treatment is rendered and the carious environment continues, the decay will progress into the dentin and eventually invade the tooth's pulp.

Dietary Factors in Dental Caries Initiation and Progression

There is abundant epidemiological evidence, both from groups that have consumed low quantities of sugar and from groups that have consumed high quantities of sugar, that sugar, and especially sucrose, is the major dietary factor affecting dental caries prevalence and progression (for review, see reference 11). One example of low consumption are the findings from a study of the Hopewood House in Australia, collected between 1947-1952. Children residing in this closely

supervised environment consumed diets that were virtually free of sugar and white flour products. Data collected from these children revealed an extremely low dental caries prevalence (0.88 decayed teeth), compared to other Australian schools (8.66) (12). The effects of high sugar consumption are best revealed from the classic Vipeholm report (13). This study was performed on 633 individuals living in a Swedish mental institution between 1945-52. It examined the effect of the frequency of sugar consumption, the timing of sugar ingestion and the consistency (retentiveness) of the sugar on dental caries rates in this population. The results showed that the addition of sugar to the diet caused increased caries activity, but the degree was very dependent on the consistency of the sugar. Sugar increased caries most if consumed between meals, and in a form that was retained for a long time in the mouth, such as toffee. The conclusions from this study, conducted a half century ago, are still well regarded today: 1. Only a small increase in caries is noted if sugar is taken with meals; 2. Sugar consumed as in-between-meal snacks is associated with a marked increase in caries increment; 3. Caries activity is greatest if consumed in the form of sticky sugar-containing candies; 4. Caries activity may vary greatly among individuals; and 5. Caries activity will decline with the withdrawal of sugar-rich foods.

Frequency of Sugar Consumption

There is only weak correlation between the total intake of sugar and the incidence of dental caries (14). However, as noted in the Vipeholm study, the frequency of ingestion, as well as the form of the carbohydrate is the critical factors in the cariogenicity of foodstuffs. Products that are sticky, retained for long periods in the mouth, or consumed with high frequency have a higher cariogenicity than foods that are eliminated quickly from the oral cavity. Therefore, frequent ingestion of hard candies, throat lozenges, etc. that contain fermentable carbohydrates can be extremely harmful to the teeth. A study using programmed feeding machines clearly demonstrated that rats exposed to a high sugar diet will experience caries according to the number of times per day a high sugar diet is presented to them. Conversely, rodents fed sugar infrequently (three times a day) experience no smooth surface caries, suggesting that the natural defenses in the mouth can counteract the damage done by bacterial acid production from moderate sugar exposure (15). Likewise, human pH telemetry studies show that subjects consuming three meals a day have periods of demineralization counteracted by periods of remineralization; however, if meal and snack periods are frequent, demineralization periods are increased and there are no remineralization periods (Fig. 2). Aside from the well-documented harm of high sugar intake on teeth, excessive sugar intake is also a concern to the general health of children. High sugar-containing foods generally are low in essential nutrients and may be substituted for more nutritious foods in a child's diet. The United States Department of Agriculture's Food Guide Pyramid clearly shows that sugar should be a very small component of the diet (16) (Fig. 3)

One example of high frequency sugar consumption is prolonged or nighttime bottle-feeding practices. Yet recent evidence suggests that, while sleeping with a bottle is an important risk factor, it is perhaps, an oversimplification of the cause of the rampant caries process. Several studies have reported that the majority of US preschool populations take, or have taken, a bottle to bed (17,18). In one study with US Head Start children, 86% of children with caries of the maxillary anterior incisors were reported to have taken a bottle to bed, but surprisingly, 69% of those who did not have maxillary anterior caries also reportedly took a bottle to bed (19). In another study, 90% of children in a population with and without caries were bottle-fed between 12 and 18 months of age, yet the prevalence of "nursing caries" was only 20% (20). Since this feeding pattern is pervasive, it follows that parents of children with early childhood caries often respond affirmatively to the question, "Do you put your child to bed with a bottle?". Thus, it is logical that the bottle-to-bed habit is inferred as the "cause" of Early Childhood Caries. Reisine and Douglass (21) have recently reviewed the studies on infant feeding patterns and found little support for the conclusion that use of a nighttime bottle is a major caries risk factor. However, despite the findings of Resine and Douglass, it is still appropriate to discourage the bottle-to-bed habit because sleeping with a bottle, especially those containing sugar, will certainly contribute to high frequency contact of substrate to the bacteria.

Another controversial, yet poorly documented caries risk is the potential cariogenicity of prolonged or nighttime breastfeeding. There are case reports associating prolonged or nighttime breastfeeding and early childhood caries (22,23,24,25). However, one cannot dismiss a possible association between reported rampant caries in these cases and other cariogenic dietary practices. Further study is required to determine the prevalence of early childhood caries in exclusively breastfed children, and whether child-rearing practices, such as lack of restriction in getting snacks (26) could contribute to caries in breastfed children as well as in bottle-fed children.

Although it is likely that Early Childhood Caries is due, at least in part, to high frequency sugar exposure from drinks in a baby bottle or sippy cup (cup with spouts) and oral colonization with ms, other causes of caries affecting the anterior teeth should be considered. Children who are four and five years old, an age by which bottle use generally has been discontinued, have been shown to develop caries in the maxillary anterior teeth (27). Data from developing countries also suggest that caries on anterior primary teeth cannot, in all cases, be attributed to inappropriate bottle use (28). For example, in Beijing, China, where the prevalence of caries in maxillary anterior teeth has been reported to be 45% in four-year-old children (29) baby bottles generally are not available. Other etiologic factors, such as hypoplasia of primary teeth and high frequency sugar consumption in solid foods, may contribute to the prevalence of this condition.

Types of Food Products

As previously mentioned various mono- and disaccharides found in the human diet support bacterial acid production and the colonization of teeth by ms. The difference in ability of bacteria to utilize glucose, fructose and sucrose in metabolism and consequently produce acid is minimal. Sucrose, however, appears to be the most cariogenic sugar, not only because its metabolism produces acid, but ms can utilize this sugar to produce glucan, a water insoluble polysaccharide. This extracellular “glue” enables ms to adhere firmly to teeth and also inhibits the diffusion properties of plaque. Inhibition of diffusion reduces the ability of buffering components of saliva to reach the sites of carious attack, and inhibits the transport of acids away from teeth. Furthermore, glucan makes the dental plaque less susceptible to mechanical disruption (30).

Fresh fruits contain various sugars and may be capable of causing caries under some conditions. However, fruit juice and fruit flavored drinks have a much greater cariogenic potential because of their high sugar content (Table 1) and the way they are often consumed. They are offered frequently to children because of their high acceptance by children, low cost, and the belief by parents that they are nutritious. Unfortunately, bottles and sippy cups filled with these fruit drinks are frequently given to children as continuous snacks, and children also are put to bed with them. Besides the caries implication of frequent consumption of fruit juice/drinks, there are reports of general health concerns about their excessive consumption (31). Their high frequency consumption, therefore, should be considered as a highly cariogenic, as well as generally unhealthy for preschoolers.

The most frequently consumed food in preschool children is milk and milk-based formula. The sugar found in milk, lactose, is not fermented to the same degree as other sugars. Additionally, it may be less cariogenic because the phosphoproteins in milk inhibit enamel dissolution (32,33), and the antibacterial factors in milk may interfere with the oral microbial flora (34). In rat caries experiments, bovine milk has repeatedly been demonstrated to be non-cariogenic and even reduces the cariogenicity of sucrose-containing diets (35,36). Human breast milk also has been shown to not cause enamel decalcification in laboratory experiments (37). Additionally, milk remineralizes artificially demineralized enamel in vitro (38). While the lack of cariogenicity of milk is clear, it may be the vehicle for more cariogenic substances. Parents are known to frequently combine milk or milk formulas with other food products or sugar (39). Additionally, those infant formulas that contain sucrose may not be as non-cariogenic as lactose-

based formulas. Additional research is needed to determine the dental implications of using infant formula that contain sugars other than lactose.

Starch is often regarded as a relatively low cariogenic carbohydrate. Human and animal experiments have generally found that starchy foods such as rice, potatoes, pasta and bread have very low cariogenicity. However, if starch is finely ground, heat-treated and eaten frequently, it can cause caries, albeit less than sucrose. Additionally, starch that is retained on the teeth long enough to be hydrolyzed by salivary amylase also can be broken down to mono and disaccharides and consequently metabolized by bacteria. Starchy foods containing substantial amounts of sucrose appear to be as cariogenic as a similar amount of sucrose (for review, see reference 11).

There is evidence that certain foods besides milk may be protective against caries. Aged cheese has been shown to be protective, because it stimulates salivary flow, and raise the calcium, phosphorus and protein content of plaque. The sugar alcohols (e.g., sorbitol, mannitol and xylitol) are sweeteners that are metabolized by bacteria at a much slower rate than glucose or sucrose or not at all. Clinical studies have shown that xylitol chewing gum even can reverse initial white spot lesions on teeth (40). The use of alternate sweeteners may work well in certain foods, such as drinks and chewing gums. However, it is difficult to replace sucrose in many foods because of sucrose's excellent properties of enhancing flavor, providing bulk and improving texture.

Nutrition Education and Counseling

Nutrition education for the purposes of reducing caries incidence in children is aimed at teaching parents the importance of reducing dietary exposures to sweet foods and hidden sugars. Education is necessary, but not sufficient to change eating behaviors. Diet counseling aims to help parents change their and their childrens' dietary behaviors so that they choose diets with low or non-cariogenic snacks, limit sweet foods to mealtimes and perform tooth brushing after sugar exposures. Dietary recommendations must be realistic and always based on current dietary behaviors of the family. It is pointless to prescribe changes that a patient cannot or will not implement. Additionally, modifications to the diet can only be made over time, aided by repetition and reinforcement. The goal must be to help caregivers develop lifelong dietary habits, which promote general and oral health for themselves and for those whom they influence.

Two Swedish studies have tested the effect of preventive education programs for new mothers on the subsequent caries experience of their children. One study provided diet and oral hygiene counseling to the test group at 6, 12 and 24 months of age, as well as fluoride supplements. This study observed a 65% lower caries experience in the 4-year-old children of

mothers who received counseling as compared to the control group. (41). Another study with a similar program found a 42% decrease in caries prevalence after 4 years (42). There also is limited evidence that preventive diet counseling can be effective for people who have serious caries problems. Two studies conducted with caries active individuals show that dietary counseling and reinforcement reduced caries increment 85% (43) and 60% (44).

Although the results of these few studies are encouraging, it is not clear why there have not been more studies to explore the potential of dietary counseling in reducing dental caries in preschool children. Clearly, there needs to be more information regarding the counseling procedures, the magnitude of effect and the costs before dietary counseling can be recommended as a routine caries preventive procedure. With the current information regarding the effect of diet counseling on caries incidence, the emphasis should be on utilizing counseling for those individuals who are at high caries risk.

Dietary Guidelines for Children at Various Ages or With Special Needs

The Prenatal Period

There is emerging interest in the effect of the prenatal period on the tooth development and the future dental caries risk of the child. The child's primary teeth have their significant formation before birth, with mineralization beginning around 3-4 months of pregnancy. At birth, the primary tooth incisor crowns are almost completely formed, and the primary canines and primary first molars are one third to one half formed. Crown completion of the second primary molars occurs approximately 1 year after birth (Table 2). During the early phase of tooth growth irreversible damage to dental tissues may occur from insults, such as inadequate nutrition, that cannot be reversed. For example, hypoplastic enamel can result from use of drugs such as tetracycline, from infections, or from maternal osteomalacia (vitamin D deficiency) (45).

Evidence from underdeveloped countries with poor nutrition shows that developmental defects (enamel hypoplasia) of the primary teeth are common (46,47). A comprehensive review has found a strong association between enamel hypoplasia and dental caries in developing countries. For instance in Pulapuka, an isolated atoll in the Pacific, developmental defects of the primary teeth have been reported to be between 51-86%, with 58-61% of these teeth developing dental caries (28). Surprisingly, a high prevalence (14%) of enamel hypoplasia also has been found in inner-city U.S. populations (49). Besides the high prevalence of enamel hypoplasia possibly due to poor prenatal nutrition, frequent enamel hypoplastic areas and subsequent dental caries in primary teeth are also found in children who are born prematurely (50). Children with

enamel hypoplasia reportedly have a 2.5 times greater risk of developing dental caries than children who do not have such defects (28).

In addition to the possible effect of poor prenatal nutrition on increased enamel defects in their offspring, mothers with active caries are more likely to the transmit cariogenic bacteria to their offspring (51). Conversely, reducing ms in mothers by means of antimicrobial agents (e.g., chlorhexidine) has been shown to reduce both the maternal transfer of these bacteria and dental caries in the offspring (52,53).

Fluoride is an important nutrient that increases the resistance of teeth. However, fluoride supplementation for pregnant women is not recommended in the prenatal period because there is little evidence that systemic fluoride (e.g., oral fluoride supplements) provided to the mother during pregnancy reduces caries prevalence in their offspring (54).

Pregnancy, thus, is a critical time to focus on preventive oral care approaches. However, a survey of expectant parents demonstrated that they were generally uninformed about dental practices, despite their high level of concern about dental health of their offsprings. Parents believed oral hygiene practices should start "early," but they were unsure at what age they should begin. In addition, they were not familiar with proper oral cleaning and tooth-brushing technique (55). In addition to lack of knowledge of dental care for their children, pregnant woman's eating habits and cravings may lead to frequent snacking on candy or other decay-promoting foods, thereby increasing their risk of caries (56).

Pregnant women therefore should be instructed on the importance, for them and for their unborn child, of a healthy diet during pregnancy. Emphasis of the Food Guide Pyramid, obtaining the majority of calories from nutrient rich foods and consuming sufficient calcium are essential. Sweets and other calorie-dense, low nutrient foods should be minimized.

Birth to One Year

Nutrition in the first year of infancy is met primarily by breast milk and/or infant formula, followed by sequential introduction of baby foods starting with fortified cereals at approximately six months. Adequate nutrition is vitally important during this period of significant tooth development. Even brief occurrences of malnutrition during the first year of life may result in enamel hypoplasia and consequently increased risk of caries (57). Breastfeeding should be encouraged because of its general health benefits and the little likelihood that this means of nutrition fosters caries. There

also is evidence that supplementing infant diets with vitamins reduces the prevalence of enamel hypoplasia (58).

Breast milk is relatively low in fluoride (59); however, infants who receive all or some of their feedings from dry powder or concentrated infant formulas may receive enough fluoride if the local water supply is fluoridated (60). Systemic fluoride supplements for those children over six months that reside in communities that are known to be non-fluoridated may be recommended (Table 3). Prescribing fluoride supplements for infants younger than 6 months of age, or supplementing a child without first determining the fluoride content of the drinking water, is not recommended because of the risk of fluorosis. Fluorosis of the teeth is generally not harmful, but can produce a visual problem (white lines) on the front teeth. Currently, it is believed that the major causes of excessive fluoride intake and subsequent fluorosis are inappropriate use of fluoridated supplements and/or unsupervised consumption of toothpastes by the child. Parents need to make sure that only a “pea-size” or smaller amount of toothpaste is used to brush a child's teeth (61). In general, systemic fluoride supplementation should not be the cornerstone of a caries prevention program because the greatest benefit of fluoride is considered to be due to its topical effect, compliance with correct dosages of fluoride is low, and a barriers exist with fluoride supplementation because a prescription needs to be written to obtain the supplement.

Children make the transition from the exclusive milk diet of infancy to a variety of foods in the first year, so this is an important time to exert positive influence over eating habits. At around the age of 6 months, when infants starts the transition from bottle to cup, it is important that they not be allowed to utilize a “sippy cup” for long periods of time since this behavior will promote caries.

Children may be introduced to sucrose-containing food and drinks at around the time of the eruption of the first tooth. While children are inclined to like sweet and salty foods and avoid sour or bitter foods, repeated experience and parental influence shape their preferences for the majority of foods. The predispositions that shape food acceptance patterns also include the fear of new foods, and the tendency to learn to prefer and accept new foods when they are offered repeatedly. Thus, the caretaker’s-feeding practices play a fundamental role in the development of the child’s choice of food types. Infants given sugars early in life favor products with higher sugar levels when they are toddlers (62,63). In addition, dental caries in three-year-old children having high exposure to various sugar during infancy is significantly greater than that of the children who had less exposure to sugar (for review, see reference 64).

Infants, especially those living in poverty, are at high risk for developing early childhood caries (65). Most implicated in this rampant disease process is prolonged use of baby bottles, during the day or night, containing highly fermentable sugars (e.g. fruit juice, soda, and other sweetened drinks), pacifiers dipped in sweet agents such as sugar, honey or syrups, or other high frequency sugar exposures. Therefore, health care providers must be aware of these harmful feeding practices and discourage them before they start. One traditional way to reduce this risk is to encourage mothers to wean the infant to a cup by one year. However, frequent exposure to sweet liquids even in a cup may also increase caries risk. Therefore, drinks (other than milk or water) either in a bottle or a cup should be limited and given mainly at main mealtimes.

Guidelines for promoting good nutrition and decreasing caries risk in infants include:

- Discourage the behavior of placing a child to bed with a bottle,
- Prohibit dipping pacifiers in sugar, honey or syrup,
- Discourage child from carrying and continuous drinking from a bottle or sippy cup
- Introduce the cup in order to begin weaning from the bottle,
- Reduce use of beverages, other than breast milk, infant formula or water,
- Follow infant feeding guidelines to insure optimal nutrition.

<u>One to Two Years</u>

Between the age of 12 and 24 months, most of the remaining primary teeth erupt, and by the third birthday, all of the 20 primary teeth have erupted. As the toddler is introduced to a variety of new foods, healthful meal and snack patterns should be instilled. Variety, moderation and attention to careful selection of between meal snacks will benefit oral and general health. Nutritious “finger foods” such as cheese, and fruit should be offered as snacks. Frequent cariogenic snacks or continual sipping of cariogenic liquids place the toddler at high risk for caries development.

Feeding behavior changes throughout the toddler years. Oral and neuromuscular development improves eating ability, increased refinement of hand and finger movement occurs and the eruption of the primary teeth leads toddlers to self-feeding. Severe lack of weight gain or “failure to thrive” may be an indicator of dental problems and these cases should be referred to a physician and dentist for diagnosis and treatment.

Figure 3 shows the Food Guide Pyramid recently published by the US Department of Agriculture (66). In a USDA survey of children’s food intake, only 2% of children consume the

recommended number of servings of foods in the Food Guide Pyramid and 11% do not meet any of the recommendations (67). High sugar intake is also of concern to general as well as dental health, since high sugar-containing foods generally are low in essential nutrients and may substitute for foods that are more nutritious (16). An example of this is the large consumption of juices by toddlers. Juice consumption has increased from 3.2 to 5.5 fl oz/day, and 11% of preschoolers consumed more than 12 fluid ounces of juice daily; and this high juice consumption, especially those high in sorbitol and fructose can cause "toddlers' diarrhea."(31).

The eating patterns of most toddlers are characterized by reduction in intake relative to size. This normal reduction in intake results from decreased growth velocity. Children tend to reject new foods up to five to ten times before they are accepted. Thus, rejected foods should be reintroduced several times by making them available and accessible (68). Caregivers should provide children with healthy foods, but let children decide for themselves when and how much to eat. This feeding strategy fosters children's reactions to internal hunger and satiety cues. However, coercive strategies to encourage young children to consume high sugar foods as "rewards" should be avoided. Additionally, cariogenic foods should be limited to mealtimes and followed by quick oral clearance, either by tooth brushing or by consumption of protective foods (69).

Guidelines for promoting good nutrition and decreasing caries risk in toddlers include:

- Discourage the behavior of placing a child to bed with a bottle,
- Complete the weaning of infants from the bottle,
- Discourage child from carrying and continuous drinking from a bottle or sippy cup;
- Limit juice or sugar containing drink intake to 4 oz. per day and only in a cup,
- Restrict cariogenic foods to mealtimes,
- Establish routine meals with family members eating together,
- Stimulate a child's appetite at meal times by reducing between meal snacking.

Two to Five Years

At this age, caregivers and health care workers need to insure that good dietary habits, including regular meal patterns, are instilled in the child. Repeated positive experiences associated with high sucrose/calorie foods tend to increase children's preferences for them. In a study of 3-5 year olds, children with a conditioned preference for high calorie foods were fatter and had higher fat diets than their peers (70).

As children approach the 4 to 5 year age range, they generally have fewer feeding and nutritional problems. However, because they are more independent food intake between

meals tends to increase. Sound eating practices learned earlier should help with appropriate snack choices. Non-cariogenic snacks should be provided at home and in lunchboxes (Table 4). Sugar-containing snacks that are slowly eaten (e.g., candy, cough drops, lollipops, suckers) should strongly discouraged.

Additional guidelines for preschoolers include:

- Promote nutritious, non-cariogenic foods for meals, as well as for snacks,
- Strongly discourage the consumption of slowly eaten, sugar containing foods,
- Encourage the majority of food consumption be at regular meal times

Children with Special Health Care Needs

Children with special needs may have greatly increased caries risk due to feeding difficulties, frequent snacking on sweets, poor oral clearance of foods, xerostomia, or chronic use of sugar-based medications. For example, children with Down syndrome, cerebral palsy and muscular dystrophy may have decreased muscle tone, often producing difficulties with sucking and/or swallowing. Such problems may prolong feeding time and food clearance, exposing the teeth to cariogenic foods for longer periods (71). Any one of these factors may greatly increase dental caries incidence in children who also present challenges in performing preventive and restorative dental care. Therefore, exceptional measures must be taken to prevent caries and other oral health problems in children with special needs. Preventive nutritional counseling that can reduce the development of oral disease in these children is essential (72).

Conclusion

Children, especially those living in low socioeconomic situations, are susceptible to dental caries, perhaps, due to poorer nutrition, less emphasis on following health behaviors and insufficient access to dental care (Fig. 4). Appropriate nutrition in early life represents a major determinant of the child's dental, as well as general health. Caregivers need information and guidance to help foster positive dietary and dental health behaviors that enable an early start to prevent dental caries in their children. Strategies should begin with the mother before birth and continue through infancy and childhood (Table 5). These nutrition and oral care guidelines should have a meaningful impact on the child's caries experience.

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Figure 1. Plaque levels showing remineralization periods and demineralization periods due to a sugar exposure.

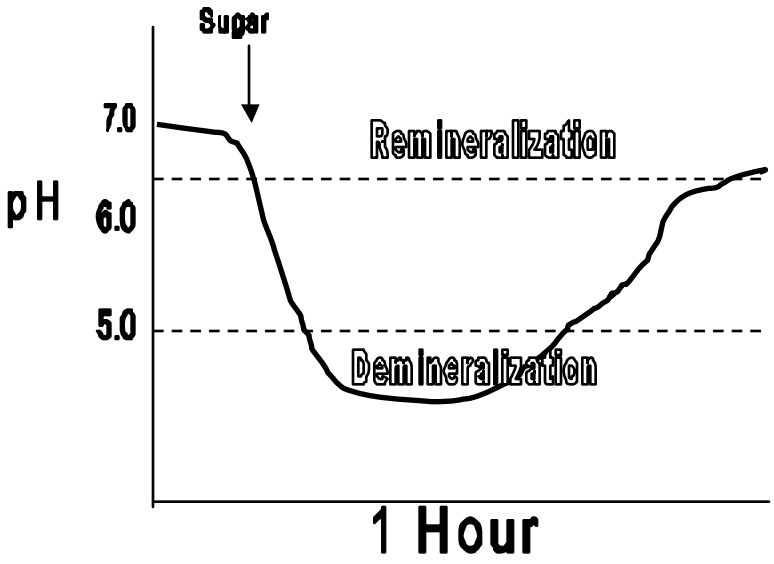

Figure 2: Example of plaque pH drops with high eating frequency. In such situations there may be greater periods of demineralization and no periods of remineralization.

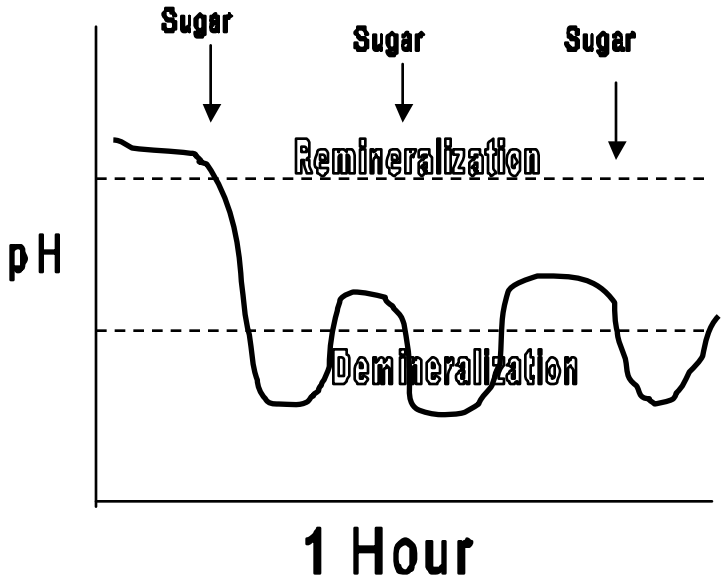

Figure 3: The Food Guide Pyramid from the US. Department of Agriculture and the Department of Health and Human Services. Foods that are predominately composed of fats and sweets (top of pyramid) should be consumed in limited quantities.

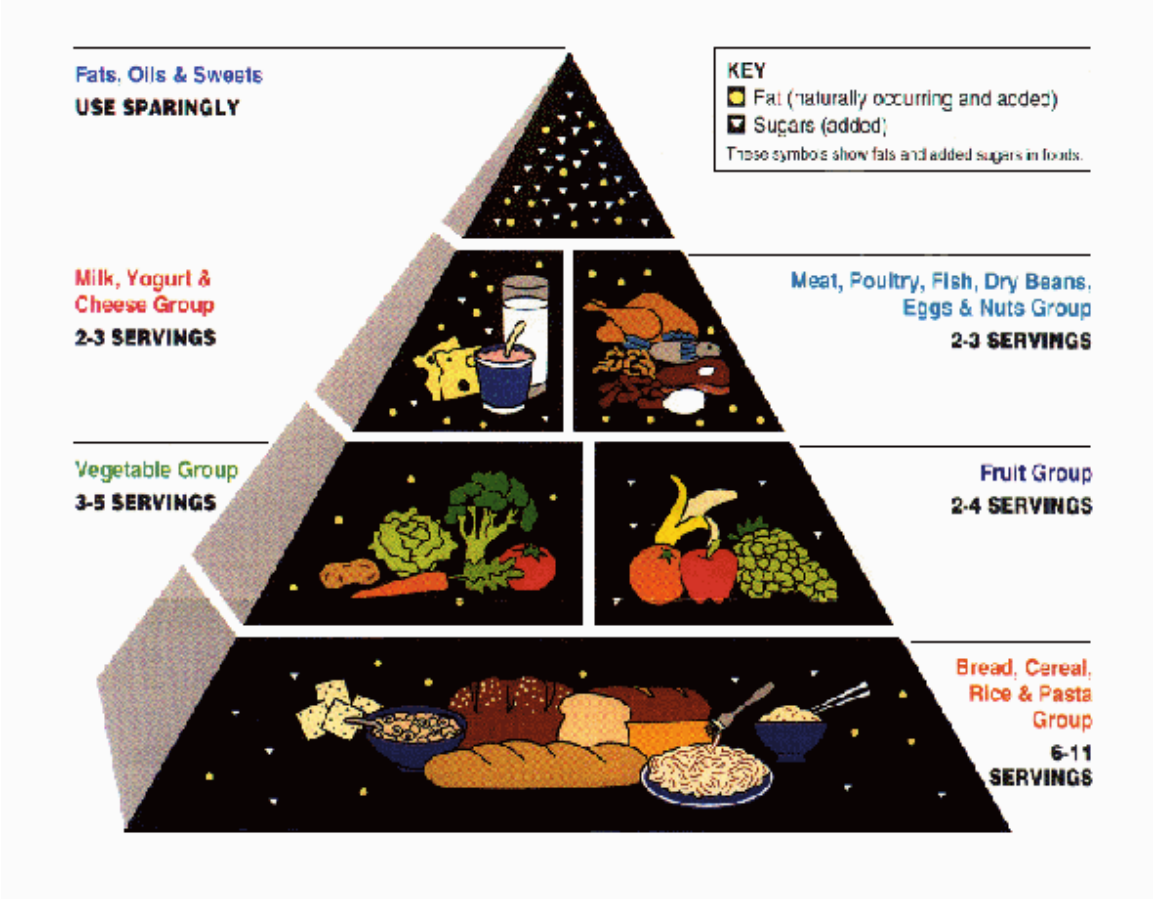

Figure 4. Contributing factors to dental caries in children living in poverty.

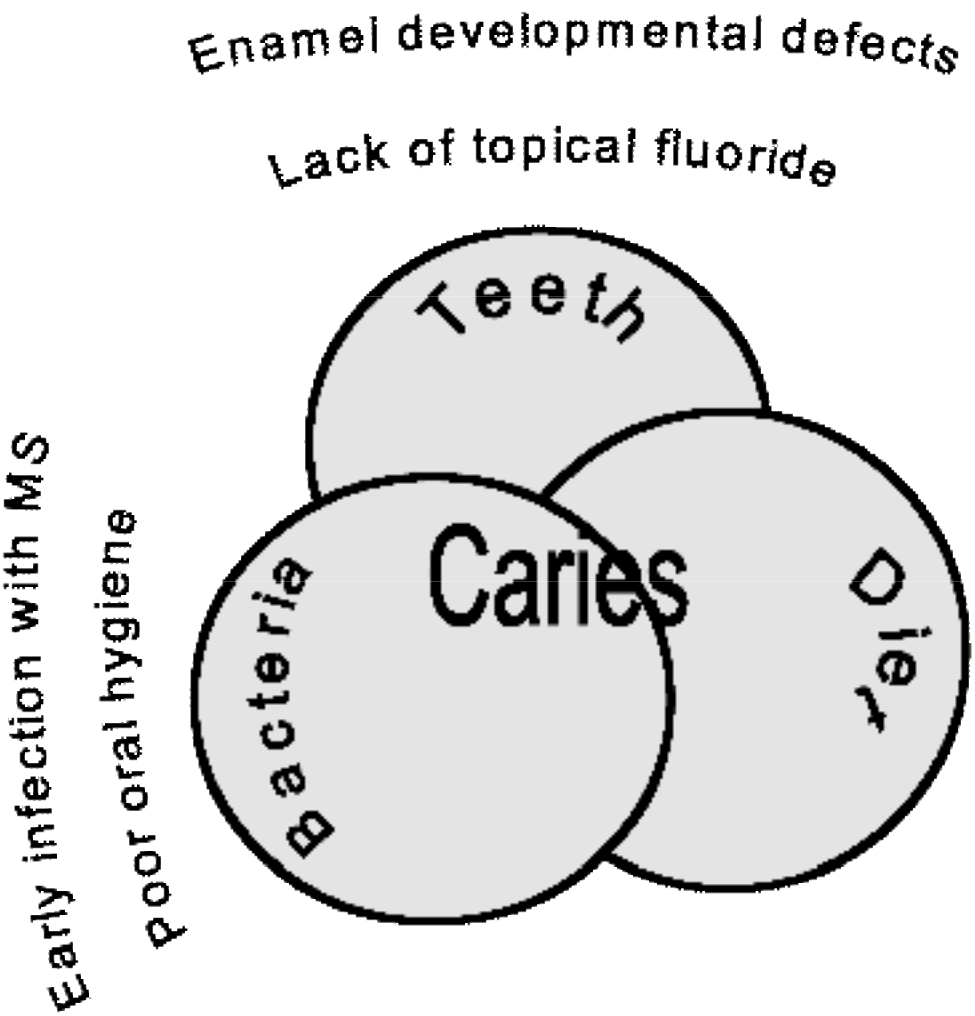

Table 1. Market basket survey of sugar content in juices or juice drinks found in a Baltimore grocery store.

Company	Label	% Fruit Juice	% Sugar	Added Sugar
Libby	Juicy Juice, Grape	100	13	no
Motts	100% Apple Juice	100	10	no
White House	Apple Juice	100	11	no
General Mills	Squeezit	1	13	yes
Johanna Foods	Ssips	10	12	yes
Tropicanna	Twister Light	10	3	yes
P & G	Sunny Delight	5	13	yes
Super G	Lemon-Lime Drink	10	13	yes
Heinz	100% Apple	100	11	no
Gerber	100% Apple	100	13	no
Gerber	Graduate Berry Punch	100	12	no

Table 2. Calcification, crown completion, and eruption times of the primary teeth.

		Tooth	First evidence of calcification	Crown completed	Eruption
Primary dentition	Upper	Central incisor	3-4 mos. *in utero*	4 mos.	7 1/2 mos.
		Lateral incisor	4 1/2 mos. *in utero*	5 mos.	8 mos.
		Canine	5 1/2 mos. *in utero*	9 mos.	16-20 mos.
		First molar	5 mos. *in utero*	6 mos.	12-16 mos.
		Second molar	6 mos. *in utero*	10-12 mos.	20-30 mos.
	Lower	Central incisor	4 1/2 mos. *in utero*	4 mos.	6 1/2 mos.
		Lateral incisor	4 1/2 mos. *in utero*	4 1/4 mos.	7 mos.
		Canine	5 mos. *in utero*	9 mos.	16-20 mos.
		First molar	5 mos. *in utero*	6 mos.	12-16 mos.
		Second molar	6 mos. *in utero*	10-12 mos.	20-30 mos.

Adapted from Logan WAG, Cronfield R. J Am Dent Assoc 1933, 20:420.

Table 3. Systemic fluoride recommendations based on fluoride content of the water and child's age.

	Fluoride Content of Water		
AGE	**<0.3 ppm**	**0.3 - 0.6 ppm**	**>0.6 ppm**
6 mo. - 3 yrs.	0.25 mg F	0 0	
3 - 6 yrs.	0.50	0.25	0
6 - 16 yrs.	1.00	0.50	0

Table 4. Cariogenic potential of children's foods and snacks

Non-cariogenic	Low Cariogenic	Highly Cariogenic
Cheeses	Fruits (except dried)	Candy
Nuts	Chocolate milk	Cookies
Dried meat sticks	Whole grain products	Cake
Plain Milk		Sweetened beverages (including fruit juices)
Vegetables		Fruit roll-ups, dried fruit
Popcorn		Breakfast bars
Flavored club soda		
Diet sodas		

 not appropriate for infants and toddlers due to potential choking problems

 sticky and/or slowly eaten candy is extremely cariogenic

Table 5: Oral health dietary guidelines for expectant mothers and pre-school children.

Dental Period	Fluoride	Nutrition
Pregnant Women	• Fluoride supplementation not indicated • Use of fluoridated toothpaste	• Follow the Food Guide Pyramid, taking into account increased needs for pregnancy • Take prenatal vitamin/mineral supplement as prescribed • Limit intake of cariogenic foods, especially as between-meal snacks
Birth to 1 Year	• Oral supplementation recommended after 6 months, if appropriate • Use of fluoridated water if available • With eruption of teeth, start tooth cleaning	• Avoid allowing the infant to sleep or nap with bottle • Avoid excessive consumption of juice • Eliminate dipping pacifiers in sweetened foods
One to Two Years	• Oral supplementation recommended, if appropriate • Use of fluoridated water if available • Tooth brushing with fluoride containing tooth paste.	• Avoid frequent consumption of juice or other sugar containing drinks in bottle or sippy cup • Encourage weaning • Continue avoidance of the bottle to bed • Promote non-cariogenic foods for snacks • Foster routine eating pattern and Food Guide Pyramid
Two to Five Years	• Oral supplementation recommended, if appropriate • Use fluoridated water if available • Tooth brushing with fluoride containing tooth paste.	• Discourage slowly eaten, sugar containing foods • Promote non-cariogenic foods for snacks • Encourage eating at meals and Food Guide Pyramid