



## Diet and nutrition in pediatric dentistry

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A child's diet, defined as the combination of foods consumed and the nutrients contained therein, has the profound ability to influence cognition, behavior, and emotional development in addition to ultimate physical growth and development. Food is merely a vehicle for nutrient delivery; nutrients provide energy for growth, serve as structural components, and participate in all metabolic functions of the body. Food, however, is more than just nutrients: sensory, emotional, social, and cultural associations influence food choices. The complex relationships among diet, physiologic requirements, and psychologic influences, as well as implications for oral health are reviewed in this article.

### **Normal growth and development**

*Normal physical growth* is defined as achievement of gradual increments in weight, height, and head circumference that parallel a standard growth trajectory and as final attainment of an adult size consistent with genetic potential. *Normal development* is defined as progressive physical, emotional, psychologic, and cognitive maturation ending in a mature state. Both the quantity and quality of food choices have the potential to enhance or interfere with normal growth and development. Physicians and dietitians typically use physical growth as an indicator that nutrient intake is appropriate for achievement of expected growth and development.

Standards for comparison of growth parameters have recently been revised by the National Center for Health Statistics Centers for Disease Control and Prevention (CDC) to better represent racial and ethnic diversity and differing patterns of growth between human milk-fed and formula-fed infants [1]. The CDC charts provide age-specific and gender-specific guidelines for weight and height from birth through 20 years of age, head

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circumference and weight-for-age from birth through 36 months, and body mass index (BMI) from 2 through 20 years.

CDC growth charts are used as a reference to evaluate a child's physical growth [1]. Three types of abnormal growth are typically recognized. First, one or more growth parameters may be lower than CDC standards. Second, one or more parameters may be higher than CDC standards. Finally, one or more parameters may deviate (ie, not track) from the previously established pattern of measurements, yet remain within the range of CDC standards. Following identification of abnormal growth, an in-depth nutritional assessment to identify dietary or medical etiologies and subsequent nutritional or medical interventions are warranted.

### *Weight*

*Weight* is defined as the heaviness of the body and is measured using a balance-beam scale [2]. Weight is used to monitor growth and provides an indication of both acute and chronic nutritional status. Weight is typically described with respect to age or height. A weight-for-age value compares the child's weight to a peer reference group. Historically, a weight-for-age value less than the 5th or 10th percentile of peer reference has been used to screen for protein energy malnutrition (PEM). Similarly, a weight-for-age value greater than the 90th or 95th percentile has been used to screen for obesity. Although the newly released CDC guidelines do not recommend using weight in this manner [1], Raynor and Rudolf [3] suggested that a low weight-for-age value is a sensitive marker of failure to thrive.

### *Stature*

Under 2 years of age, *stature* is defined as recumbent length and is assessed using a length board with a stationary head and adjustable foot [2]. After 2 years of age, stature is defined as height in a standing position and assessed with a stadiometer or with the heels, buttocks, and head flat against a tape measure imbedded in a wall [2]. Both length-for-age and height-for-age values compare the child's height to a peer reference group. Historically, a height-for-age value less than the 5th or 10th percentile of a peer reference group has been used to screen for PEM. CDC guidelines define a height-for-age value less than the fifth percentile as *short stature* [1].

### *Weight-for-height ratio/BMI*

Weight-for-height ratios describe the relationship between the two variables and, when compared with reference values, provide an assessment of the appropriateness of this relationship. The revised CDC guidelines provide weight-for-height references for young children [1]. For children 2 to 20 years of age, BMI references are provided for each age [1]. The BMI is the weight-for-height relationship most reflective of body fat and is

calculated by dividing the weight (kilograms) by the height (meters), squared [4]. Historically, a weight-for-height ratio less than the 5th or 10th percentile has been used to screen for PEM; CDC guidelines define a ratio less than the fifth percentile as underweight [1]. Historically, weight-for-height ratios greater than the 90th to the 95th percentile have been used to screen for obesity. Current CDC guidelines define the 85th to less than the 95th percentile as *at risk for overweight* and define greater than the 95th percentile as *overweight* [1].

### **Pediatric dietary guidelines**

Guidelines for both dietary habits and food choices are designed to provide adequate energy and nutrient intakes to support expected physical growth and emotional, psychologic, and cognitive development. Energy and nutrients are the required substances; foods and beverages are merely the vehicles that deliver these substances. Foods chosen for consumption and the manner of consumption, however, impact both energy and nutrient intakes. The consistency and texture of food and the nutrient requirements change with growth and development of the child. Most food choices are ultimately influenced by senses, emotions, and the environment. Pediatric dietary guidelines are summarized by age in Table 1.

### *Nutrient requirements*

The central theme of pediatric nutrition is growth—the accretion of body tissue. Both energy and nutrients must be available for growth to occur. Although every child is unique, the Dietary Reference Intakes [5] provide age-specific and gender-specific guidelines to assure adequacy of nutrient intakes and to limit risk of nutrient toxicity. The body compensates for variation in daily intakes by using stores during times of inadequate intake and by increasing storage or excretion during periods of excessive intake. Energy requirements are determined by basal metabolism, food assimilation, and physical activity. Energy metabolism is tightly regulated; energy stored in adipose and muscle tissues is used during periods of dietary deficits, whereas excess dietary energy is stored as adipose tissue during periods of excess. Under normal circumstances, energy intake slightly exceeds energy expenditure, allowing for accretion of body tissue during childhood.

The Food Guide Pyramid categorizes foods of common origin and similar nutrient content into food groups [6]. In such classification systems, the energy, fat, and sugar concentrations are extremely variable within food groups. Food processing typically leads to foods with lower nutrient and higher fat, sugar, and energy concentrations. Dietary guidelines recommend consumption of a variety of foods from all food groups to achieve adequate nutrient and appropriate energy intakes [7].

Table 1  
Dietary guidelines by age

Age	Texture	Nutrients	Foods	Meal patterns	Notes
Birth–6 mo	Liquid	Energy-dense Recommended Dietary Intakes	Human milk Infant formula	On demand	Infant formulas provide 100% nutrient needs Human milk may be supplemented with iron and vitamin D
6 mo–1 y	Liquid Gradual transition from pureed to fork-mashed foods	Energy-dense Recommended Dietary Intakes	Human milk Infant formula Commercial infant or home-prepared foods	Initiate structure: three meals and three snacks	Introduce cup; expect majority of liquid to be consumed by bottle Cows' milk is not appropriate Human milk may be supplemented with iron and vitamin D
1–2 y	Liquid Chopped table foods	Energy-dense Recommended Dietary Intakes Source of iron	16–24 oz/d human milk, toddler's formula, or cows' milk Table foods Limit 100% juice to 4–6 oz/d	Structure: three meals and three snacks	Transition to cup when oral motor skills allow 100% of fluid needs to be consumed by cup Children refusing meat or iron-fortified foods require iron supplementation
2–5 y	Avoid foods presenting choking hazard	Gradually reduce fat intake Recommended Dietary Intakes Source of iron	Food Guide Pyramid 16–24 oz milk/d Limit 100% juice to 4–6 oz/d Limit soft drinks to 6 oz/d	Structure: three meals and three snacks	Children refusing milk require calcium and vitamin D supplementation

6–12 y	30% of energy from fat Recommended Dietary Intakes	Food Guide Pyramid Limit 100% juice to 8–12 oz/d Limit soft drinks to 12 oz/d	Structure: three meals and one to three snacks	Children refusing milk require calcium and vitamin D supplementation
12+ y	30% of energy from fat Recommended Dietary Intakes	Food Guide Pyramid Limit soft drinks to 12 oz/d	Structure three meals and one to three snacks	Children refusing milk require calcium and vitamin D supplementation Menstruating females may need iron supplementation

Infancy is characterized by tremendous growth and, therefore, energy and nutrient requirements are highest during this stage of life. Because infants have immature digestive, absorptive, and excretory systems, however, they have difficulty digesting complex foods; may manifest allergic responses to foreign proteins; and are unable to excrete high renal solute loads. To consume adequate energy and nutrient intakes, frequent feedings of energy-dense human milk or infant formulas are recommended. Provision of water, juice, infant cereals, or sugared beverages, which provide minimal energy and limited nutrients, are not recommended during early infancy.

The *transition stage of infant nutrition* is defined as the period of change from a primarily liquid diet to acceptance of solid foods, and typically occurs between 6 and 20 months of age. Energy requirements per unit body weight gradually decline, whereas total nutrient requirements gradually increase. The older infant is more mature and able to digest most foods. Foods associated with increased risk of allergy (eg, cows' milk, egg white) or infant botulism (eg, honey) are not recommended until after 1 year of age. An energy-dense diet is recommended through 2 years of age. Although opinions differ, a decline in fat intake to 30% of total energy is recommended by 5 years of age. Throughout childhood and adolescence, diets based on nutrient-dense foods and beverages are recommended, with energy-dense foods and beverages for occasional use. The United States Department of Agriculture's *Dietary Guidelines for Americans* [7] recommend limiting simple sugars to 10% of total energy—the equivalent of 12 oz/day of soda pop for a 6-year-old or 16 oz/day for a 12-year-old. The American Academy of Pediatrics recently issued recommendations for limiting intake of 100% juice and emphasizing increased consumption of whole fruits [8].

### *Physical development*

The physical stage of development determines the form and texture of foods consumed during infancy and early childhood. Infants are born with elementary rooting and sucking reflexes necessitating delivery of energy and nutrients in liquid form through a nipple. The extrusion reflex, which aids in sucking but causes the infant to expectorate solid foods, is present at birth. Relaxation of the extrusion reflex, development of tongue transfer (ie, movement of food from the front to the back of the mouth), maturation of the swallow, and development of both head control and independent sitting are signs that the infant is ready to attempt infant foods (eg, thin, pureed). Provision of infant foods prior to this time is frustrating for the caregiver and for the infant: little is consumed, choking is a risk, and the infant is unable to signal satiety.

Development of fine motor skills allows the infant to finger feed. Early use of palm grasp matures into a thumb-finger pincer approach during

the latter half of the first year. Beginning at about 6 months, infants are able to close their lips around a cup; however, most infants are unable to consume adequate liquids by cup until about 1 year of age. Discontinuation of the bottle should only occur when the infant has demonstrated the ability to consume sufficient liquids by cup. Closed-cup systems, some with straw mechanisms, offer a few advantages over bottles but are often selected by caregivers because of their portability and minimal spillage.

During early childhood, biting and chewing skills continue to mature. Young children remain at risk for choking even with advanced chewing skills. Unless modified, large round foods (eg, hot dogs, grapes, peas, carrots) should be avoided to reduce choking risk [9,10]. Furthermore, talking or laughing with food in the mouth and eating during active play or while running should be discouraged to limit risk of choking.

### *Emotional development*

Beyond nutrition, food functions as a source of nurture. Foods have symbolic meanings, are associated with secular and religious holidays, and are used to portray wealth. “Upper crust,” “bring home the bacon,” “turkey,” and the “clean plate club” exemplify the interwoven nature of food and culture. Social and emotional relationships with food begin very early in life and, when distorted, can have lasting repercussions.

Newborns are dependent on their caregivers for every facet of existence. *Bonding* is a term used to describe the healthy relationship that develops between the infant and caregiver. During early infancy, regular and adequate nutrition fosters a secure emotional attachment; disruption of either may contribute to impaired bonding [11]. Likewise, substitution of food for emotional feedback may lead to an inappropriate relationship with food [12,13].

The transition stage of infant nutrition represents a time of exposure to new smells, flavors, and textures. Throughout early childhood, repeated exposure is often required for acceptance of new foods [14]. The latter half of the transition stage coincides with the infant’s initial attempts at autonomy, more commonly known as the “terrible twos.” Caregiver attempts to control the type and quantity of food consumed by the infant may lead to mealtime struggles and subsequent growth problems. At the same time, a child’s every whim does not need to be answered with foods or beverages. Provision of adequate foods at regular intervals allows the child to develop a secure relationship with food. Ellyn Satter, a registered dietitian and social worker, suggested that “parents are responsible for what is presented to eat and the manner in which it is presented. Children are responsible for how much and even whether they eat” [15]. The reader is referred to Satter’s texts [15,16] for more information on dynamics of the feeding relationship. Spruijt-Metz et al [17] recently reported that maternal

pressure to eat and concern regarding a child's weight explained 15% of the variation in total fat mass of children aged  $11 \pm 1.7$  years, after correction for both lean body mass and energy intake [17]. Thus, parents have the potential to positively or negatively impact dietary habits and subsequent growth throughout childhood and adolescence.

Having food to share during a famine is a status symbol. In times of plenty, though, bestowing excessive quantities of highly palliative food on children is a form of indulgence, may lead to confusion between food and love, and may contribute to the development of emotional eating. As children struggle to achieve emotional maturity, caregivers must reinforce healthy eating practices. Although access to appropriate and adequate food is necessary, caregivers must help the child differentiate between physiologic hunger and emotional eating.

### *Environmental influences*

A child's food choices and dietary habits are influenced through peer pressure, accessibility, and marketing [18–20]. These influences may be positive or negative. As a child's first role model, the parent encourages acceptance of novel foods by eating them with the child. Likewise, the parent encourages acceptance of energy-dense foods by consuming them in the child's presence. Parents often forbid foods considered nutritionally inadequate; such efforts may backfire when the child gains independent access to the "forbidden fruit" at an older age. Furthermore, using a treat to bribe a child to consume an undesirable food places undue emphasis on the bribe and does not lead to increased acceptance of the undesirable food [14,21].

Peer acceptance becomes increasingly important throughout childhood and adolescence. From a food perspective, this means eating as peers do. Although peer influences may be positive, all adolescents are testing the water. As teens struggle for independence, parental guidance regarding food choices is not well received. Satter's [15] division of responsibility for children also applies to teens [15]. Parents, as caregivers, have the right to determine what foods are purchased and available for consumption in the home. This right includes the responsibility to provide nutritionally appropriate foods within defined meal and snack patterns. On the other hand, teens should be allowed the autonomy to make their own dietary choices away from home.

Food companies sell their products through television advertising. Saturday morning cartoons are accompanied by commercials promoting energy-dense highly palatable foods [22]. Indirect advertisement through sponsorship of youth activities, school contracts, and assorted gimmicks are used to influence older children's and teens' food choices [18]. At the point of purchase, combination meals and super-sized foods influence the type and quantity of foods consumed [20].



## Nutrition-related pediatric disorders

Malnutrition is defined as a bad diet or nutritional state due to excessive (eg, toxicity), inadequate (eg, deficiency), or an unbalanced intake. Although poverty exists in the United States and some individuals cannot afford a nutritionally adequate diet [23], the majority of nutrition-related disorders in this country are associated with excessive or unbalanced intakes. Most food choices are not based on their inherent nutrient content or relationship to concurrently consumed foods but are selected based on their palatability, emotional associations, ease of access, and peer acceptance. Thus, nutrition-related pediatric disorders frequently observed in this country are not due to access issues but to inappropriate food choices. Treatment of these disorders is not as simple as prescribing the appropriate diet; rather, it requires behavioral changes with respect to food choices and dietary habits. Furthermore, each child has a unique response to his or her environment and must be treated on an individual basis. A high-quality diet established early in life and reinforced by health professionals throughout life will reduce risk of both oral and systemic disease.

### *Early childhood caries*

*Early childhood caries* (ECC) has been defined as “the presence of one or more decayed (noncavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth” in children from birth through 71 months of age [24]. As discussed in the article by Mobley (this issue), the caries process is characterized by site-specific demineralization of a tooth surface by acid produced locally during fermentation of carbohydrate by oral bacteria. The risk pattern and severity of caries changes with age in young children. Therefore, age-specific definitions have been proposed to distinguish severe ECC from ECC [24]. Severe ECC is characterized by the presence of (1) one or more decayed, missing, or filled smooth surfaces in children less than 36 months; (2) cavitated, filled, or missing (due to caries) smooth surfaces in the primary maxillary anterior teeth; or (3) multiple decayed, missing, or filled surfaces in children aged 36 to 71 months [24].

ECC is a preventable childhood disease affecting disproportionate numbers of children from low-income households and racial minorities [25]. The social and medical consequences of ECC are enormous; ECC has been associated with self-esteem issues, missed school days, behavioral problems, oral pain, impaired eating, oral abscesses, and poor growth [26–29]. Treatment of ECC often requires hospitalization. Furthermore, previous caries experience is a risk factor for caries in the permanent dentition [30].

The etiology of ECC is multifactorial; the presence of oral bacteria and fermentable carbohydrates are necessary, yet proper oral hygiene and regular fluoride exposure reduce the risk of caries. Several species of bacteria found in the oral cavity have been associated with the caries process; however, the presence of *Streptococcus mutans* is most commonly associated

with ECC [31]. Colonization typically occurs after tooth eruption when *S mutans* can attach to the hard surface. Genetic analysis of the bacteria found in young children suggests that the transmission of bacteria is typically from mother to child [32,33]. Although a “window of infectivity” hypothesis suggested that colonization during a specific time frame is associated with ECC, recent data suggest that later infectivity will allow the caries process to occur [34,35].

Delayed or abnormal progression through the transition stage of infant nutrition may predispose the child to ECC by increasing quantity or frequency of carbohydrate exposure. Excessive reliance on beverages for nutrition (particularly high-sugar beverages), with delayed acceptance of solid foods and delivery of these beverages by bottle or closed-cup system, may increase risk of ECC. Lack of transition to structured meal and snack events during this stage that results in a “grazing” meal pattern may predispose the child to ECC. Continued nocturnal bottles or other eating events combined with decreased saliva during sleep may contribute to ECC risk. Although breast-feeding is generally considered protective against ECC, prolonged breast-feeding has been associated with ECC [36,37].

Prevention of ECC requires early evaluation of dietary habits and anticipatory guidance. Dietary guidelines that support appropriate transition to table foods, the provision of a variety of foods from all food groups at structured meals and snacks, and limited intake of sugared beverages are appropriate for ECC prevention. Proper diet education, however, may not be sufficient to prevent ECC. Parents must be able to differentiate between their children’s needs (eg, hunger, diaper change, distress) to prevent nurturing their child with food. Parents also need to understand the adverse outcomes associated with emotional eating in order to decrease caries risk. Early screening of dietary habits by health care providers who see infants and young children and appropriate counseling or referral to a pediatric dentist and dietitian may prevent ECC.

### *PEM/failure to thrive*

*PEM* is defined as weight or height less than the 5th to the 10th percentile for age or a weight-for-height ratio less than the 5th to the 10th percentile, whereas failure to thrive implies a deficit in expected growth and in one or more areas of psychosocial development [38–40]. *PEM* is caused by inadequate protein and/or energy intakes secondary to inadequate resources, oral motor deficits, or underlying systemic disease. Failure to thrive is associated with psychosocial deprivation (eg, inadequate or inappropriate nurturing, lack of stimulation) and inadequate nutrition.

The presentation of *PEM* reflects the severity and duration of the disorder [39]. Chronic, mild *PEM* typically presents with short stature and a normal weight-for-height relationship. In addition, the crossing of percentiles (eg, 75th percentile for weight-for-height ratio at age 2 years falling

to 25th percentile for weight-for-height ratio at age 3 years), reflecting a reduction in expected linear growth with maintenance of a normal weight-for-height ratio, is also consistent with chronic, mild PEM. By contrast, a weight-for-height ratio or BMI below the 5th through the 10th percentile is indicative of chronic, severe PEM when accompanied by short stature and is indicative of acute PEM when accompanied by normal height. Weight-for-age values less than the 5th through the 10th percentile have historically been considered indicative of PEM.

PEM places a child at risk for permanent physical, cognitive, behavioral, and emotional growth deficits. Although physical catch-up growth may occur, it may not fully compensate for lost growth. Concurrent and permanent cognitive, behavioral, and emotional issues have been attributed to PEM in childhood [39].

The etiology of PEM is multifaceted and may accompany failure to thrive. Although the disease manifests due to deficits in protein and/or energy, entire food groups are typically missing from the diet. Thus, the child is often deficient in multiple nutrients. Inadequate or inappropriate food intake may result from dysfunctional caregiver-child interactions leading to food refusal; unstructured meal patterns in which the child grazes on low-nutrient, preferred foods and refuses nutrient-dense offerings at meals; excessive intake of low-nutrient beverages (eg, juice, juice drinks, soft drinks) that provide energy and satisfy the appetite but do not provide nutrients needed for growth; rigid food preferences resulting in acceptance of a limited number of foods; and oral motor difficulties resulting in delayed transition to solid foods and inability to consume adequate quantities.

Prevention and treatment of PEM require recognition of the underlying pathology and appropriate intervention. Early identification of oral motor deficits and rigid food preferences may prevent caregiver-child struggles and frustration in the feeding arena in addition to allowing for normal growth. Signs consistent with dysphagia include excessive oral secretions, prolonged feedings, poor tongue control, pocketing food, or strong texture preferences [41,42]. Rigid food preferences are consistent with sensory integration difficulties often observed in children with pervasive developmental disorders [43]. Children with recognized oral motor deficits or rigid food preferences should be referred to a pediatric developmental clinic. For most children, screening for structured meal patterns and appropriateness of food offerings will identify children at risk for PEM. Referral to a pediatric dietitian and reinforcement of normal pediatric nutrition guidelines are warranted.

### *Obesity*

Both the prevalence and severity of childhood obesity are increasing at alarming rates in developing countries. Although defined as excessive body fat, obesity is typically diagnosed based on weight and weight-for-height

measures. CDC guidelines suggest refraining from using the term *obesity* when working with children and prefer the terms *at risk for overweight* and *overweight* [1]. Weight-for-age values greater than the 90th to the 95th percentile may be used to screen for overweight; however, the weight-for-height relationship provides a much more valuable assessment of body fat. An age-specific weight-for-height ratio or BMI from the 85th percentile to less than the 95th percentile is indicative of at risk for overweight, whereas an age-specific weight-for-height ratio or BMI greater than the 95th percentile is indicative of overweight [1].

Obesity-related diseases (eg, type 2 diabetes mellitus and cardiovascular disease) are second only to tobacco-related diseases as a cause of preventable death in the United States and place a tremendous burden on our public health system [44]. Although children do not typically die from obesity-related complications, childhood obesity is not benign [45–50]. Obese children and adolescents are at increased risk of cardiopulmonary disease, sleep apnea, mobility difficulties, type 2 diabetes mellitus, and social stigmas of obesity. Children who manifest obesity during childhood are at an increased risk of becoming obese adults [51]. In addition to size, body shape (eg, high waist-to-hip ratio, central adiposity) and adipocyte size (eg, large, hypertrophy) have been associated with increased risk of hyperinsulinemia, hyperlipidemias, and hypertension in adults [52–54]. The impact of body shape and adipocyte size in young children on future disease risk is not clear, but the obese child is at increased risk for obesity-related diseases in adulthood [45,47–50].

Body weight reflects the balance of energy input and output. A deficit of energy leads to weight loss; an excess to weight gain. Growth is normal in children and, by definition, weight gain is expected. Energy consumed in excess of that required to support expected weight gain, however, is stored as fat in adipose tissue. Factors influencing either side of the equation will influence weight gain. Declining activity, environmental influences, dietary habits, and food choices are implicated in the current obesity epidemic [55]. Pursuit of sedentary activities such as television and video games, lack of physical chores, and educational emphasis on academic rather than physical development have been suggested as reasons for declining energy expenditure. The development and marketing of highly palliative energy-dense foods, super-sizing, and school soft-drink contracts are examples of environmental influences leading to excessive energy intake [18–20]. Dietary habits encouraging excessive intake include a decline in structured meal patterns (in particular, the constant consumption of energy-containing beverages), eating on the run, and eating while engaged in other activities (eg, television viewing). Selection of highly processed energy-dense foods may also increase energy intake.

A rudimentary understanding of fat cell metabolism is necessary to fully appreciate the difficulties associated with treating obesity. Energy homeostasis is tightly regulated by the neuroendocrine system, including the

afferent (eg, leptin, insulin), central nervous system (eg, neuropeptide Y, norepinephrine), and efferent (eg, appetite, sympathetic nervous system) components [56]. Adipocytes store energy as fat and function to release energy in response to dietary deficit or take up energy in response to dietary excess. Normal adipocytes typically hold 0.5  $\mu\text{g}$  of fat and resist change. During excessive energy intake, energy is stored in adipocytes until a maximal size is attained, at which point adipocytes divide and preadipocytes differentiate, with each cell having a normal quantity of fat [57]. A deficit of energy that reduces adipocytes below their comfort zone is associated with compensatory responses to conserve energy and increase food intake [57]. Unfortunately, adipocytes do not go away during weight loss; when formed, fat cells are relatively permanent and resist reduction below their comfort zone. A small number of preadipocytes and adipocytes are lost through apoptosis [58]. Although the obvious treatment of obesity is decreased energy intake, at some level, the body perceives this as a “starvation” state and resists additional weight loss. Perception of the starvation state is moderated through adipocyte size, not quantity of body fat. Thus, after it is gained, successful loss of all excessive fat may not be physiologically possible. Therefore, prevention of obesity beginning in childhood is essential. Screening to identify dietary habits, food choices, and behaviors that place a child at risk for obesity and subsequent intervention are necessary. The oral health professional typically sees patients for routine office visits more frequently than a physician and is in a unique position to screen children, referring those at increased risk to their physician or a pediatric dietitian.

### *Fructose malabsorption*

Fructose is a monosaccharide found naturally in fruits. Absorption of fructose occurs in the small intestine by way of one of two mechanisms. In the presence of glucose, fructose is absorbed by active transport and, when consumed alone, fructose is absorbed by facilitated diffusion [59]. The capacity to absorb free fructose is limited in children and some adults, resulting in an osmotic diarrhea. In severe cases, toddler’s diarrhea secondary to excessive fruit juice consumption has led to PEM [60]. With our increased understanding of fructose malabsorption, adults with a history of “irritable bowel syndrome” have recently been more accurately diagnosed with fructose malabsorption.

Although present in the human diet throughout history, two relatively recent developments have resulted in increased dietary consumption of fructose. First, the marketing of fruit juice as a healthy beverage has led to increased consumption of juice during infancy and early childhood. Second, consumption of high-fructose corn syrup, which was introduced in the late 1960s, has quadrupled during the past 20 years, with three fourths of high-fructose corn syrup used in soft-drink production [61]. High-fructose corn

syrup sweetens comparably to sugar, resists crystallization, and provides textural benefits to food manufacturers.

For individuals suffering from fructose malabsorption, fructose intake is limited to prevent symptoms. Children can typically tolerate some fructose but not large doses. Again, an emphasis on less processed foods is recommended.

### *Disordered eating*

Although the term *eating disorders* is often used interchangeably with anorexia nervosa and bulimia nervosa, other types of disordered eating are recognized by the American Psychiatric Association [62], typically secondary to or coexisting with another psychopathology. Anorexia nervosa, bulimia nervosa, and similar disorders (eg, binge eating disorder, female athlete triad, compulsive overeating) are discussed in the article by Faine (this issue) and will not be reviewed here. Eating disorders characteristic of young children with implications for the oral health professional, however, are discussed.

*Psychosocial dwarfism* is characterized by deceleration of linear growth and characteristic behavior disturbances including bizarre eating patterns and sleep habits [63,64]. Children with this disorder do not demonstrate expected growth in response to appropriate food intake in their home environment secondary to neglect and/or severely dysfunctional caregiver-child interactions. Children with psychosocial dwarfism demonstrate severe food insecurity behaviors including polyphagia and polydipsia, gorging with vomiting, stealing and hoarding of food, and eating garbage or pet food. Typical presentation occurs at 18 to 48 months.

*Rumination* is defined as the voluntary regurgitation, chewing, and reswallowing of stomach contents [62]. Rumination is a self-stimulatory behavior and is typically associated with psychosocial issues and/or mental retardation. The age of onset is typically 3 to 12 months but occurs later in individuals with mental retardation. Children with rumination are at risk of enamel erosion due to exposure of the oral cavity to gastric contents.

*Pica* refers to the pathologic craving for a food item or substance not commonly regarded as food [62]. Classic examples include starch, ice or paint chips, dirt, and paper, although the author has encountered less typical substances including feces and the absorbent filler of disposable diapers. Pica increases the risk of direct toxicity from the desired substance and lead poisoning from incidental exposure.

A number of children and adults demonstrate disordered eating or unusual food habits. Examples include preoccupation with food, extreme food-seeking behaviors (eg, foraging in garbage, stealing from other's plates), and no evidence of satiety. These behaviors are consistent with genetic disorders affecting the satiety center (eg, Prader-Willi syndrome), history of head injury, severe mental retardation, and history of severe neglect.

Treatment approaches for eating disorders are twofold. Both management of the underlying social situation or psychologic disorder and environmental control of the feeding situation are warranted. An interdisciplinary team including a physician, psychologist, nurse, and dietitian develop an individualized comprehensive management program. In some instances (eg, Prader-Willi syndrome), the drive for food is so great that the child may never be able to assume independent control of his/her diet. Recognition of disordered eating by the oral health professional is reason for referral of the child to a pediatric developmental clinic.

### *Osteoporosis*

Osteoporosis is characterized by low bone mass leading to enhanced bone fragility and increased fracture risk [65]. Although the clinical outcome of this disease presents in later life, osteoporosis has recently been described as a pediatric disease. Accrual of bone mass parallels linear growth during adolescence, with slight gains continuing through early adulthood. Attainment of a high peak bone mass is the first line of defense against later fracture risk. Because current treatment strategies are not able to rebuild bone but merely limit its demise, current research is focused on attainment of peak bone mass during adolescence and early adulthood.

The Food and Nutrition Board of the Institute of Medicine recommends 1300 mg/day of calcium during adolescence for attainment of peak bone mass [66]. Survey and experimental studies suggest that many young children and adolescents are not consuming adequate calcium [67,68]. Milk is the primary dietary source of calcium and vitamin D in the United States. Although several vegetables are high in calcium, the quantities required for achieving adequate intakes are unreasonable or the calcium is bound to phytate or oxalate, which prevents absorption. Most types of supplemental calcium are absorbed similarly to calcium found in milk and are appropriate for individuals who refuse milk and other dairy products [69]. The reader is referred to the article by Bronner (this issue) for a comprehensive review of calcium metabolism and osteoporosis.

### *Iron deficiency*

Iron deficiency anemia is an important pediatric public health problem in the United States, although the prevalence has declined in recent years [70]. Iron deficiency anemia is defined as reduced hemoglobin production secondary to insufficient iron. In young children, iron deficiency anemia is usually due to inadequate dietary intake. In adolescent females, menstrual blood loss coupled with inadequate dietary intake contributes to iron deficiency.

Iron is essential for brain development and normal immune function. Iron deficiency anemia has been associated with long-term cognitive loss, growth problems, and behavioral problems [71,72]. Although children

respond rapidly to iron supplementation, changes in cognition and behavior are often permanent.

Young children are typically screened for iron deficiency anemia through Special Supplemental Food Program for Women, Infants, and Children clinics and at well-baby exams. Normal hemoglobin and hematocrit values are a prerequisite for transitioning to cows' milk at 1 year of age. Most infants are born with iron reserves sufficient to last through 6 months of age; provision of dietary iron after this time point will prevent iron deficiency. Although absorption of iron is limited, infant formulas with iron, iron-fortified infant cereals, and infant meats provide sufficient iron during infancy. Both human milk and cows' milk contain limited quantities of iron; supplementation is recommended for infants consuming only human milk after 6 months. If iron-containing table foods (eg, meats, fortified cereals) are not accepted at the time that cows' milk is introduced, then supplemental iron is recommended. Adolescent females may require iron supplementation to prevent iron deficiency anemia, particularly if red meat products are avoided. Liquid iron supplements may stain teeth and care should be taken to limit exposure to erupted teeth.

### **Dietary habits and oral health**

Both dietary habits and food choices determine substrate availability for growth of oral bacteria. The role of fermentable substrates in plaque development and subsequent caries or periodontal disease is reviewed extensively in the articles by Mobley and Bronner (this issue). Nutrient intake and subsequent nutritional status influence tissue health and immune system function. Implications for periodontal disease are reviewed in the article by Boyd and Madden (this issue). The role of food choices, dietary habits, and food environment in pediatric caries risk are discussed in this section.

#### *Food choices*

All foods and beverages can fit into a healthy diet when dietary principles of moderation and balance are respected. As supported by the Food Guide Pyramid [6], a variety of nutrient-dense foods should form the base of the diet, with low-nutrient energy-dense foods included within individual energy requirements.

Although fermentable carbohydrates are found in both natural and processed foods, more highly processed foods contain fewer nutrients, are higher in energy, and have more easily fermented carbohydrates than natural foods. Grain processing includes multiple steps, with each successive step degrading the starch molecule into a more readily fermented carbohydrate [73]. For example, corn meal produced by grinding is minimally cariogenic; corn flakes produced by steaming, rolling, and drying of corn grits are more cariogenic; and high-fructose corn syrup produced by



hydrolyzation of cornstarch and subsequent inversion of glucose to fructose is highly cariogenic. Food processing concentrates naturally occurring sugar in selected foods (eg, fruit juice, confections) and hydrolyzes starch bonds that when combined with sugar (eg, brownies, wafer cookies), appear to increase cariogenicity. Thus, to minimize cariogenicity and support systemic health, highly processed foods should be consumed in limited quantities.

### *Dietary habits*

Historically, dietary assessment and recommendations for oral health have focused on the sugar content of foods consumed, with little attention paid to the manner of consumption. Secular changes in family structure, meal patterns, and environmental time demands have led to dietary patterns that impact caries risk and systemic health as much as the foods themselves.

Structured meal and snack patterns are ideal for both oral and systemic health. Defined meal patterns encourage food security, allow for development of an appropriate appetite, and limit the time for exposure to cariogenic foods. A daily habit of three meals and three snacks, each 30 minutes in length with an additional 30 minutes for the plaque pH to return to normal, theoretically supports 6 hours of demineralization and 18 hours of remineralization. Rapidly growing children and adolescents require frequent opportunities to consume energy to support growth; restrictive meal patterns (eg, three meals, no snacks) are inappropriate.

In addition to structured timing, the meal environment deserves comment. From a nutritional perspective, the meal should focus on eating, with few distractions (eg, television, reading) and minimal stress. Both distractions and stress negatively affect the quality and quantity of food consumed, ultimately impacting both oral and systemic health.

Unfortunately, multiple obligations that vie for limited time may prevent families from enjoying traditional structured meals. Implications of alternative meal patterns for oral and systemic health are outlined as follows:

### *Skipping meals*

The natural response to skipping meals is “bingeing” due to severe hunger when eating occurs. Such bingeing may result in excessive energy intake. During infancy, delayed feedings may interfere with normal attachment. Limitation of energy intake early in the day (breakfast) may impair mental and physical performance [74]. Skipping meals may also lead to energy conservation by interfering with the body’s feast-fast cycle.

### *Snacking*

When small quantities of foods are consumed throughout the day, a person may never become truly hungry. The result is an increased intake of highly palliative, processed foods. Such habits allow for multiple

exposures to fermentable carbohydrates and subsequently increase caries risk. Depending on the degree of snacking and the nature of foods consumed, snacking may lead to inadequate energy intake with weight loss, excessive energy intake with weight gain, or inadequate nutrient intake.

### *Drinking*

Frequent intake of energy-containing beverages increases risk of dental caries and may blunt the appetite. Such beverages may or may not displace nutrient-dense foods or beverages, leading to inadequate nutrient intake or excessive energy intake. Historically, oral health education has emphasized early transition to drinking from a cup to limit exposure time associated with bottle-feeding. Unfortunately, many cups currently in use are not significantly different from a bottle, and oral health instruction should emphasize consumption of energy-containing beverages at defined meal and snack times.

### *Subconscious eating*

Eating while preoccupied with other, typically sedentary activities such as television viewing, computer use, or reading may decrease awareness of what or how much is consumed. Increased exposure time impacts caries risk and increased food consumption impacts weight. Pacifying young children with food rather than tending to their actual needs encourages subconscious, emotional eating.

### *Environment*

The statement “change is both good and bad” applies to the evolution of the food environment. Current agricultural production and preservation technologies and transportation systems provide most citizens with abundant food choices. Modern food processing, including the production of high-fructose corn syrup, has enabled food manufacturers to create numerous highly palatable energy-dense foods with stable shelf lives at a reasonable cost. The current food environment has implications for both oral and systemic health.

Perhaps most concerning, from both nutritional and oral perspectives, is the increased production and consumption of regular soda pop and other sugar-containing beverages, in all probability at the expense of milk consumption [67,75]. Excessive consumption and prolonged sipping of regular soda pop are associated with rampant caries in children and adults [76]. Fruit juice is marketed as a healthy beverage for young children, but excessive intake may increase caries risk. Although sports drinks (eg, Gatorade,<sup>®</sup> Pepsi Co, Inc., Purchase, NY) have been available for years, they are currently being consumed as recreational beverages by youth. Sports drinks are acidic sweetened beverages, with the potential to increase caries risk. From a systemic perspective, all sweetened beverages may

contribute to excessive energy intake and limit intake of other nutrient-dense foods and beverages. Calcium and vitamin D intakes are of particular concern, with apparent decreases in milk intakes.

Children live in a climate in which foods and beverages are both abundant and readily accessible. School and youth activities, malls, play centers, and convenience stores promote food and beverage consumption as part of the experience. As busy families have less time to prepare meals at home, eating on the run has become more common. To attract customers and maintain customer satisfaction, “biggie sizes” are routinely offered by fast-food companies. Although “biggie sizes” may appear to be a financial bargain, they typically contain more energy than most youth and adults require. In addition, it may be impossible to consume a “biggie” serving during a reasonable time frame (eg, 64 oz soda pop in 30 minutes), with implications for prolonged exposure.

## **Dietary counseling in pediatrics**

### *Objective*

The obvious objective of dietary counseling in pediatric oral health is caries prevention. If prevention is indeed the objective, then diet assessment and preventive recommendations must begin at an early age, prior to visible signs of the carious process. Diet-related diseases including caries and obesity are chronic. Manifestation of a carious lesion or the presence of excessive body fat is an outcome of the disease process and, when present, is extremely difficult to treat through diet and nutrition therapy. Inappropriate dietary habits and unhealthy food preferences developed during childhood have lifetime implications, particularly with respect to cardiovascular disease and osteoporosis. Therefore, it is not appropriate to wait until the oral or chronic disease manifests; every child’s diet should be screened and evaluated at regular intervals. Undesirable dietary habits and food choices should be identified, appropriate recommendations provided, or referrals made to limit disease risk.

### *The patient*

When providing dietary counseling in pediatrics, identification of the “patient” requires careful consideration. Individual recommendations are appropriate during infancy and the transition stage of infant nutrition when dietary patterns and food choices differ sufficiently from other family members. Dietary recommendations that differentiate the older child from the family unit, however, are seldom successful unless the recommendation limits an adverse stimulus (eg, as observed with celiac disease or peanut allergy) that the child has internal motivation to prevent. Therefore, dietary assessment and recommendations should be offered within the family

context. Although family members may have different nutrient requirements, basic recommendations for dietary habits and food choices apply to everyone. Parental attitudes and behaviors require evaluation. For example, the mother who purchases diet soda pop for her obese daughter may appear to be supportive; however, the child receives a very different message when this same mother maintains a stock of regular soda pop for other family members and repeatedly tells the daughter, “I don’t have to drink that diet stuff.”

### *The problem*

Prior to providing dietary counseling, the problem must first be identified. Pediatric nutrition-related diseases are typically due to inappropriate dietary habits or food offerings, caregiver-child interaction problems, oral-motor delays, and underlying psychiatric or systemic diseases. Oral health professionals have a responsibility to recognize the problem, provide dietary counseling for oral implications, and refer to appropriate health professionals for comprehensive treatment. Furthermore, oral health professionals have an opportunity to support both oral and systemic health by reinforcing dietary recommendations provided by other health professionals.

### *Counseling*

Breaking any habit is hard, and changing dietary habits is extremely difficult; however, changing dietary habits is not impossible. The patient should be informed of the present disease or disease risk, and the diet-related etiology should be explained. Concurrent implications for systemic disease may underscore the significance for the patient. Patient-specific alternative behaviors and food choices consistent with current resources, lifestyle, and cooking skills should be offered. Undesirable dietary habits, appropriate recommendations, and rationale for these recommendations are provided in Table 2.

The patient is responsible for implementing dietary changes; however, the oral health professional can facilitate these changes by empathizing with the patient. The oral health professional should (1) recognize that changing dietary habits is difficult but early intervention may be most successful; (2) encourage small changes at one time because multiple changes may be overwhelming, causing the patient to revert to prior habits; (3) reinforce the disease-risk diet-associated etiology and complement positive behavioral changes; and (4) present “how-to” rather than “don’t” recommendations because they are more likely to be successful.

The oral health professional also should interview adolescents separately from their parents. Individual interviews require that teens take an active role in their nutrition counseling and assume responsibility for their dietary habits. Individual interviews may illicit information that the parent does not

Table 2  
Dietary recommendations for specific problems

Undesirable diet-related behavior	Recommendation	Rationale
Excessive candy consumption	Provide miniature candy bars at meal/snack Keep out of sight	Miniature size limits quantity of consumption but does not deny food, thus reinforcing its role as an "other" food for occasional use Storing out of sight limits stimulus to request
Refusal of new foods	Do not require consumption Continue to offer Should child choose to taste, allow to spit out Do not provide treats for tasting	Forced feeding does not encourage long-term acceptance Multiple exposures to new foods required before child willing to taste Allows the child an out if unable to swallow, making more comfortable with trying new foods Bribes typically increase desirability of preferred treat and reinforce undesirability of the offending food
Requests alternative food	Provide planned meal Include one preferred food Do not provide substitutes	Requests for alternative foods are characteristic of autonomy and independence struggles Cooking special foods provides the child with inappropriate control of the feeding situation and can exacerbate caregiver-child struggles By providing a preferred food in unlimited quantities, the child has access to food and will not go hungry
Irregular meal patterns	Provide regular meals at similar times every day	For young children, irregular meals predispose to snacking and may contribute to food insecurity
Poor meal appetite	Provide structured meals/snacks Provide only sugar-free beverages between meals/snacks	Frequent snacking blunts the appetite Frequent consumption of energy-containing beverages blunts the appetite
Binge eating	Provide six structured meals and snacks at regular intervals	Bingeing typically results from excessive hunger or food insecurity
Snacks "forbidden" foods	Provide appropriate quantities of "forbidden" foods at meals/snacks Remove "forbidden" foods from environment	Allowing access to "forbidden" foods without judgment limits their perceived importance Parent is responsible for providing access to appropriate foods Reinforce parental authority
Excessive regular soda pop consumption	Provide diet soda pop or other sugar-free beverages	Diet soda pop or other sugar-free beverages are not associated with increased caries risk or excessive energy intake

know; confidentiality should be respected. The oral health professional should work with the parent to provide an environment in which the adolescent can succeed, being careful not to get caught in negative interactions between the parent and teen.

## Summary

Optimal growth and development are the primary objectives of pediatric nutrition. Dietary habits and food choices to support both oral health and systemic health are similar. Each emphasizes structured meal patterns and food choices. The oral health professional has a responsibility to screen for diet-related disorders and to treat or refer as appropriate.

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