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Nutrition, oral health and the young child

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Abstract

Oral health is integral to general health and essential to well-being and quality of life. Socio-behavioural and environmental factors play a significant role in oral disease and oral health. Dental caries is a global disease with few populations exempt from its effects. In developing countries, as development increases so does dental caries and children are at the forefront of the disease disadvantage. There is a growing need to identify high caries risk groups accurately to commence prevention from a young age. The effect of early intervention in childhood on general and dental health with both population and high-risk approaches also needs examining. As an educational tool, the paediatric food-based dietary guidelines may play a significant role in nutrition and oral health interventions. This paper provides information on nutrition, including access to fluoride and use of sugar. Oral health concerns, such as early childhood caries, which are important for the young child, are also discussed.

Keywords: oral health, nutrition, food-based dietary guidelines, pre-school children, South Africa.

In order to address the great need for oral health education, oral health guidelines have been included in the paediatric food-based dietary guidelines (PFBDGs). This paper provides support for the relevant PFBDGs, namely 'Clean your baby's mouth regularly' for the 0–6 months age group, 'Teach your baby to drink from a cup' for the 6–12 months age group and 'If children have sweet treats or drinks, offer small amounts with meals' for the 1–7 years age group.

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Oral health means more than good teeth; it is integral to general health and essential to well-being (Petersen 2003). The interrelationship between oral health and general health has been proven. Severe periodontal disease, for example, is associated with diabetes (Grossi & Genco 1998). The strong correlation between several oral diseases and non-communicable chronic diseases is primarily the result

of common risk factors (Sheiham & Watt 2000). Oral health and nutrition have a synergistic relationship. Oral infectious diseases, as well as acute, chronic and terminal systemic diseases with oral manifestations, impact on the functional ability to eat while also having an impact on diet and nutrition status. Similarly, nutrition and diet may affect the development and integrity of the oral cavity as well as progression of diseases of the oral cavity, and are major multifactorial environmental factors in the aetiology and pathogenesis of oro-facial diseases and disorders (US Department of Health and Human Services 2000).

Despite great achievements in oral health of populations globally, problems still remain in many communities. The significant role of socio-behavioural and environmental factors in oral disease and health has been demonstrated by a large number of epidemiological surveys (Petersen 2003). Dental caries is a global disease with few populations exempt from its effects. In developed countries, widespread reduction of dental caries in childhood has led to the development and recognition of high caries risk communities who have failed to benefit from prevention and are often excluded from regular use of healthcare systems (Gratrix & Holloway 1994). The communities are often of low socio-economic status, where minority ethnic groups are over-represented and general health and living conditions are poor (Acheson 1998).

In developing countries, as development increases, so does dental caries, and children are at the forefront of disease disadvantage (Chen *et al*. 1995). Internationally, there is a growing realization of the need to accurately identify high caries risk groups, to commence prevention from a young age and to examine the effect of early intervention in childhood on general and dental health with both population and high-risk approaches (Pine & Pine 1997). Critical aspects to consider are: social and cultural aspects around child development, including family stress, and access and use of health services; nutrition, including access to fluoride and use of sugar; composition and activity of the oral microflora; and a recognition of behavioural and biological impacts on health. Published research has looked at associations between key risk factors and the development of dental caries in children cross-sectionally and some longitudinally (Hausen 1998). However, in developing countries particularly, little is known of the interactions vertically in the paradigm between molecular impacts and psychosocial impacts, particularly within and between ethnically diverse or disadvantaged, impoverished children.

Dental caries is widely recognized as a preventable infectious disease that is strongly modified by diet. The main players in the aetiology of the disease are cariogenic bacteria, fermentable carbohydrates and a susceptible tooth and host. However, in young children, bacterial flora and host defence systems are in the process of being developed, tooth surfaces are newly erupted and may show hypoplastic defects, and their parents must negotiate the dietary transition through breast/bottle feeding, first solids and childhood tastes and so it is thought that there may be unique risk factors for caries in infants and young children (Seow 1998).

Oral health of children in South Africa

The results of the 1999–2002 National Children's Oral Health Survey showed that dental caries was more severe in the primary than the permanent dentition. In the 6-year-old group, the caries prevalence of 60.3% is higher than the Department of Health's goal for the prevention of dental caries which was set at 50% caries free 6-year-old children by the year 2000 (Department of Health 1994). The Western Cape Province had the highest prevalence for dental caries in all age groups. Based on weighted national means the Unmet Treatment Needs Index (UTN) was 92% for the 4–5 years olds and 91.4% for the 6 years olds. Both the caries prevalence and UTN differed widely in the different provinces (Table 1). The report concluded by saying that: 'The prevention of early childhood caries should be an important priority for provinces' and 'every effort should be made to encourage and promote positive oral health habits' (Van Wyk *et al*. 2004).

Early childhood caries

Early childhood caries (ECC) in infants and preschool children is a preventable dental disease. Milnes

Table 1. Prevalence of dental caries and untreated caries in the primary dentition by age group and province in South Africa

Age group	4–5 years old		6 years old	
	% Caries	% Untreated caries	% Caries	% Untreated caries
Weighted national mean	50.6	46.6	60.3	55.1
Western Cape	77.1	72.0	82.3	75.2
Northern Cape			72.1	70.9
Eastern Cape	58.9	53.7	67.7	63.6
Free State	60.1	57.8	59.2	56.8
Kwazulu Natal	52.4	50.8	64.8	59.9
Gauteng	49.1	37.6	59.7	50.5
North-west	41.0	39.5	52.3	48.2
Mpumalanga	40.2	35.1	56.2	48.4
Limpopo	31.3	30.8	37.2	33.8

(1996) reported that while the prevalence rate of ECC varied from 1% to 12% in developed countries, in developing countries and within disadvantaged populations of developed countries (immigrants, ethnic minorities), the prevalence rate is as high as 70%. The presentation of a child suffering from rampant caries is, as described by Fass (1962), a shocking experience. He published the first comprehensive description of caries in infants, which he termed 'nursing bottle mouth'.

The clinical appearance of ECC includes the form of caries affecting all the primary upper anterior teeth, upper and lower primary first molars and the lower canines (the lower anterior teeth remain unharmed) to rampant caries affecting all the teeth in the mouth or small 'pockets' of decay affecting a single tooth in children between 1 and 5 years old. The answer to the question 'what causes early childhood caries?' is an important, albeit a complex one. It concerns those in both the developed (Holt & Downer 1996; Wendt *et al*. 1996) and developing countries (Mattee *et al*. 1994; Feng & Liu 1999). Understanding the aetiology of the disease has a direct influence on public policy.

In the United Kingdom, the British Society of Paediatric Dentistry recommends a reduction in sugar intake by the whole child population in the country, whereas its American counterparts' view is that sugar restrictions can be relaxed in a society where fluoride is used frequently, particularly for children who have low or no caries (British Society of Pediatric Dentistry 1992; American Academy of Pediatric Dentistry 1989). How aetiology is interpreted also influences the design of interventional programmes set up to prevent the disease.

It has been established that a group of cariogenic micro-organisms, oral streptococci, is associated with ECC. Oral levels of these bacteria, which are generally acquired from the mother, were found to be elevated in children with ECC (Tinanoff & O'Sullivan 1997). Other contributing factors that predispose children to ECC include prolonged and night-time bottle feeding of milk and/or sweetened juice in infants and toddlers, nocturnal breastfeeding after 12 months of age, linear hypoplasia of primary teeth associated with malnutrition and the prolonged use of a pacifier covered with honey, sugar or other sweetened foods (Tinanoff & O'Sullivan 1997; van Palenstein Helderman & Soe 2006).

The seriousness and societal costs of ECC continue to be a significant health issue, especially for children from racial/ethnic minorities and from developing countries. There is considerable evidence that children who experience ECC continue to be at risk for new lesions as they get older, both in the primary and permanent dentitions (Kaste *et al*. 1992; Litt *et al*. 1995; O'Sullivan & Tinanoff 1996). ECC has also been implicated as contributing to other health problems: children with ECC were shown to weigh less than 80% of their ideal weight and to be in the lowest 10th percentile for weight (Acs *et al*. 1999). Low *et al*. (1999) reported on the effect of severe caries on the

quality of life in young children. They found that there was a significant change in pain complaint, eating preferences, quantity of food eaten and sleep habits before and after treatment of dental caries. Finally and most importantly, the cost of restoring decayed teeth in ECC is extremely high (Weinstein 1998).

Implications of early childhood caries

Early childhood caries is characterized by a high prevalence, high impact and high resource requirements. Its seriousness and societal costs are enormous, especially among racial or ethnic minorities (Tinanoff & O'Sullivan 1997). There is considerable evidence that children who experience ECC continue to be at high risk for new lesions as they grow older, both in the primary and permanent dentitions (Johnsen *et al*. 1987; Kaste *et al*. 1992; O'Sullivan & Tinanoff 1993). It has not been established whether it is the high levels of infection by cariogenic organisms or the establishment of poor nutritional practices that are the determinants of caries progression (Litt *et al*. 1995).

Treatment of ECC is expensive, often requiring extensive restorative treatment and extraction of teeth at an early age. In the US, the estimated costs of restoring teeth alone is thought to exceed U$1000 per child (Jones *et al*. 1995). In addition to these expenses, general anaesthesiaor deep sedation may be required because such young children lack the ability to cope with the procedures. One study has also implicated ECC as contributing to other health problems. The mean age of 'low weight' patients with nursing caries was significantly greater than for patients at or above their ideal weights, indicating that progression of nursing caries may affect growth adversely.

In addition, the quality of life of the child suffers – pain or infections associated with ECC may make it difficult for the child to eat. Alternatively, poor nutritional practices may be responsible for both the reduced weight and caries. Thus, the consequences of ECC are a significant problem not only in monetary terms of the parents and the government, but also in potential risks to health and comfort of the child.

Prevention of early childhood caries

There are three general approaches that have been used to prevent ECC. The first is a community-based strategy that relies on the education of mothers or caregivers in the hope of influencing their dietary habits as well as those of their infants (Ripa 1988). This approach also uses water fluoridation and community preventive programmes in high-risk communities. The second approach is based on the provision of examination and preventative care in dental clinics. The third involves the development of appropriate dietary and self-care habits at home. All three approaches use the mothers or caregivers to follow healthy dietary and feeding habits in order to prevent the development of ECC, as patterns in the introduction of foods and when eating behaviours are established, may be influential in its prevention and treatment (Garcia-Godoy *et al*. 1995; Tinanoff & Palmer 2003).

The goal of the educational initiative is to increase the knowledge of the mother and to improve the dietary and nutritional habits of the infants and mothers. It is assumed that an increase in the knowledge of mothers or caregivers will influence their self-care habits and dietary practices and in turn improve the dietary and oral hygiene habits of the infants leading to the prevention of ECC.

Dental caries

Dental caries in young children causes unnecessary pain and expense. Furthermore, children with craniofacial problems, neurological abnormalities or impaired cognitive abilities are at a greater risk for oral infectious diseases that can interfere with appropriate responses to feeding protocols. Diet and nutrition have a direct influence on the progression of tooth decay. Preventive dental regimens are designed to maintain the equilibrium in the dynamic demineralization–remineralization of the tooth surface (Featherstone 2000). Included in the regimen are measures for diet counselling, fluoride therapy, use of fissure sealants and the control of cariogenic bacteria. Nutrition education by oral healthcare workers and nutrition counselling by dietetic and

other healthcare workers must address dietary risk factors associated with oral disease.

The evidence shows that sugars are undoubtedly the most important dietary factor in the development of dental caries. Dental caries is probably the disease most strongly associated with sugar consumption. The ability of oral bacteria, most notably *Streptococcus mutans,* to ferment sucrose and other sugars into acid, producing a sustained pH lower than 5.5, is the basis of the demineralization process that is capable of destroying tooth enamel and eventually leading to tooth loss. The biochemistry of disaccharide breakdown and the formation of sticky levans and dextrans in the formation of plaque on the tooth surface, providing a protected reservoir for bacterial acid production right on the tooth surface, is also well-established.

The frequency and the total amount of sugar-rich foods consumed have both been strongly correlated to dental caries and also to each other, suggesting that strategies to control one variable will contribute to controlling the other (Sheiham 2001). Other researchers (Ismail *et al*. 1984; Jamel *et al*. 1997) have shown the danger of consuming sugar in forms that are very sticky (have strong adhesive properties) as these are cleared from the mouth by saliva very slowly.

Factors determining the cariogenic, cariostatic and anti-cariogenic properties of the diet are food consistency (liquid, solid, sticky, long-lasting), frequency of consumption of sugar and other fermentable carbohydrates, nutrient composition, potential to stimulate saliva, sequence of food intake and combinations of food (Papas *et al*. 1995; DePaola *et al*. 1999; König 2000) (Table 2).

Fluoride

The ability of fluoride to protect teeth against dental caries is well-established. However, the association between the frequency of sugar intake and dental caries is negated only partly by the presence of fluoride (Stecksen-Blicks & Holm 1995). In fact, the beneficial effects of fluoride vary according to the amount of sugars consumed (Kunzel & Fischer 1997). For example, there is a dramatic increase in the prevalence and severity of dental caries when sugar intake increases from around 15 kg to 35 kg per person per year (Takahashi 1961; Sheiham 1987). On the basis of this evidence, Sheiham (1991) recommended that in the presence of fluoride, a 'safe' intake of sugars would be up to 15 kg person^{-1} year^{-1} and in the absence of fluoride, up to 10 kg. For South Africa, it has been recommended that the sugar intake should be <40 g day^{-1} in areas where the water in not fluoridated and <55 g day^{-1} in fluoridated areas (Steyn *et al*. 2003).

Water fluoridation – where are we?

Optimum fluoride levels in the water strengthen the teeth and reduce tooth decay by up to 60% (Pizzo *et al*. 2007). Tooth decay is at unacceptably high level in certain communities in South Africa and it is likely that these levels will increase, especially among the poor. Water fluoridation is the process of adjusting the amount of fluoride that is present naturally in a community's water to the optimal level for protection against tooth decay. It is a cheap public-health measure. The cost of adjusting the existing fluoride

Table 2. Definitions of oral health terms

Cariogenic	Foods/drinks containing fermentable carbohydrates that can cause a decrease in salivary pH to <5.5 and demineralization when in contact with micro-organisms in the mouth.
Cariostatic	Foods that are not metabolized by micro-organisms in plaque and subsequently cause a drop in salivary pH to <5.5 within 30 min
Dental caries	An oral infectious disease of the teeth in which organic acid metabolites produced by the metabolism of oral micro-organisms lead to demineralization and destruction of the tooth.
Early childhood caries	Rampant dental caries in infants and toddlers.
Gingivitis	Inflammation of the soft tissue of the gums.
Periodontal disease	Oral disease characterized by inflammation and destruction of the attachment apparatus of the teeth, including the ligamentous attachment of the tooth to the surrounding alveolar bone.
Tooth erosion	The gradual loss of enamel of the tooth because of chemical, not bacterial, processes.

concentration in the water supply is about one Rand per person per year. It is the most cost-effective way of preventing tooth decay. It is 18 times cheaper than toothpaste and 61 times cheaper that filling one tooth (van Wyk *et al*. 2001).

In 2000, the Minister of Health, under section 37 of the Health Act, 1977 (Act no. 63 of 1977), after consultation with the Minister of Water Affairs and Forestry, made provision in the schedule that every water provider must practise fluoridation. To date, implementation process has stalled because of various complex infrastructural and financial issues at a local government level.

Dental erosion

Dental erosion is the chemical dissolution of dental hard tissues without bacterial involvement. It is commonly associated with dietary practices involving the frequent intake of acidic food and beverages (Scheutzel 1996; Zero 1996; Parry *et al*. 2001) that weaken the integrity of the tooth and increase caries risk. Dental erosion may progress into the dentine and pulp, with consequent tooth sensitivity, altered occlusion and poor aesthetics. The scientific interest in dental erosion has dramatically increased during the last decade and it is now recognized as an important cause of loss of tooth tissue in children. Furthermore, the reduced thickness of enamel and greater acid solubility in the primary dentition contribute to higher susceptibility to erosion (Shaw *et al*. 1998; Harley 1999).

The prevalence of erosion is associated with social and dietary factors (Millward *et al*. 1994; Hinds & Gregory 1995; Malik *et al*. 2001; Luo *et al*. 2005). There is a positive correlation between higher parental educational levels and erosion in children. Previous studies reported inconsistent findings on the relationship between erosion and social factors: Luo *et al*. (2005) and Millward *et al*. (1994) found that children from low socio-economic groups had less erosion, while others found an inverse relationship that as social deprivation worsened, the presence of dental erosion increased (Hinds & Gregory 1995; Harding *et al*. 2003). A focus on the importance of improved dietary habits for good oral health as well as good general health should be included in counselling.

Periodontal diseases

Periodontal diseases are oral infectious diseases involving inflammation and loss of bone and supporting tissues of the teeth. Although its pathogenesis involves bacteria, there are local and systemic factors that influence the severity and progression of the disease (Nishida *et al*. 2000). Nutrient deficiencies (vitamin C and calcium) may compromise the systemic response to inflammation and infection and alter nutrient needs (Nishida *et al*. 2000; Krall 2001). In addition, it can also compromise the associated inflammatory response and wound healing (DePaola *et al*. 2002). Nutritional status has a direct influence on the synthesis and release of cytokines and their action (Psoter *et al*. 2005). Consequently, malnutrition is associated with increased needs for calories and protein to promote repletion, wound healing and an improved immune response (Enwonwu 1995).

Malnutrition also has an adverse effect on the volume, composition, antibacterial and physiochemical properties of saliva. Good nutritional status and dietary practices combined with the removal of the stimuli of the inflammatory periodontal response are important in reducing the severity of periodontal diseases.

HIV/AIDS

The oral manifestations of HIV infection include fungal, viral and bacterial infections. Neoplasms, periodontal disease, salivary gland disease and lesions of uncertain origin are also seen. Oral lesions such as candidiasis, herpetic ulcers and Kaposi's sarcoma are among the first symptoms of HIV infection. Because of the magnitude and impact of HIV-associated oral disease on dietary intake and nutritional status, dental intervention together with nutrition management is an essential component of care.

Children with HIV infection are at risk for oral disease accompanying nutritional and systemic consequences. For example, oro-pharyngeal candidiasis may cause a burning, painful mouth and dysphagia.

Herpes simplex and cytomegalovirus infections lead to chronic, painful ulcerations. These conditions cause discomfort, difficulty with swallowing, eating restrictions and may reduce an already compromised appetite and intake.

Infants and children

Adequate nutrients are needed pre-, peri- and postnatally for normal growth and development of the oral cavity (Alvarez 1995; DePaola *et al*. 1999; DePaola *et al*. 2002). One episode of mild to moderate malnutrition in the first year of life and/or folate deficiency was associated with increased incidence of caries in deciduous and permanent teeth later in life (Alvarez 1995; US Department of Health and Human Services 2000).

Diet counselling is an integral part of anticipatory guidance during the infant oral health visit. Similar to dietary instructions for children of all ages, the primary emphasis is on sugar intake frequency. Maxillary anterior incisor caries manifested in ECC mainly because of feeding practices is the major nutrition-related oral disease found in young children. As mentioned above, the combination of infant/child feeding practices and repeated sequential consumption of fermentable carbohydrates, such as sweetened beverages or highly processed starchy/sugary foods, increases caries risk. For school-age children, meal and snack behaviours should involve food choices that promote oral health. Other conditions that may affect oral health include developmental anomalies that alter eating ability and require specialized feeding strategies and cranio-facial surgery, which causes increased energy, protein and nutrient needs for wound healing.

There are, however, other infant-specific dietary issues that must also be addressed during the infant oral health visit. Bottle-fed infants should not be put to sleep with the bottle. Weaning from the bottle should be encouraged by 12–14 months of age. Infants older than 6 months and with exposure to less than 0.3 p.p.m. fluoride in their drinking water need dietary fluoride supplements of 0.25 mg fluoride per day. Only 4–6 oz of fruit juice should be consumed by infants per day. Infants should not be given powdered beverages or fizzy drinks, as these pose increased risk for dental caries. Iron-fortified infant cereals, along with breast milk or infant formula, should be consumed by infants who are over 6 months of age. Cow's milk should be avoided in the first year of life and restricted to less than 24 oz per day in the second year. Parents should be cautioned regarding the potential of various foods to constitute a choking hazard for infants (Nainar & Mohummed 2004; Sayegh *et al*. 2005).

Nutrition education and counselling for the purposes of reducing caries in children are 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 cup; discouraging the behaviour of a child sleeping with a bottle; promoting non-cariogenic foods for snacks; fostering eating patterns consistent with Food Guide Pyramid and those food that have been fortified; 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. sweets, lollipops, suckers). Along with nutritional factors, a comprehensive approach to preventing dental caries in pre-school children must include improved general dietary habits, good oral hygiene, appropriate use of fluorides, and access to preventive and restorative dental care (Tinanoff & Palmer 2003). Policies and health promotion strategies need to be targeted to mothers from less advantaged backgrounds. Appropriate advice on infant feeding, dietary practices and oral hygiene measures should be the major focus.

Concluding remarks

Evolving issues in nutrition and oral health

Oral health in dietetic and nursing education

Because a healthy, functioning oral cavity is a necessary part of mastication and digestion, a comprehensive oral health module should be incorporated into the didactic and clinical training of dietetic students.

The outcomes should include detection of nutrition- and diet-related risk factors for oral health and referral to an oral healthcare worker for any abnormal findings. The need for oral health professionals to facilitate patient referrals has been identified abroad (Greenspan *et al*. 1995; Touger-Decker & Gilbride 1997). Dietetic students should be given opportunities to work in oral health settings together with dental students to provide competency in oral examination, identification of oral risk, nutrition and diet advice and interventions.

Collaborative approaches to nutrition and oral health education

A joint World Health Organization/Food and Agricultural Organization (WHO/FAO) expert recommendation (WHO/FAO 2003) encouraged international organizations, including the WHO/FAO, to recognize nutrition as an essential part of training of oral health professionals, as well as an important part of educational programmes for dietetics and other health professionals. Oral health and nutrition experts should assume leadership in promoting this dual curriculum content area of allied health professionals. Oral health and dietetic professionals need to form networks with other members of the healthcare team (physicians, nurses, speech and language therapists, etc.) to advance health promotion and preventive initiatives that promote oral health and nutrition as they relate to general health.

Partnerships in practice

Partnerships need to be forged between national dental organizations, local and national governmental structures and the private sector to alleviate the barriers (physical, cultural, racial, ethnic, social, educational, environmental and healthcare delivery) that prevent people from achieving oral health and to enhance and support appropriate research that explores new ways of improving oral health for the nation. Opportunities to carry nutrition into the oral health arena are open to dietetic professionals who are knowledgeable about oral health and related public health initiatives, such as the PFBDGs which may prove to be a useful educational tool. These collaborative endeavours in research, education and service delivery will ensure that comprehensive health care is provided for persons with oral problems.

References

Acheson A. (1998) *Independent Inquiry into: Inequalities in Health*. Report. Her Majesty's Stationery Office: London.

Acs G., Shulman R., Ng M.W. & Chussid S. (1999) The effect of dental rehabilitation on the body weight of children with early childhood caries. *Pediatric Dentistry* **21**, 109–113.

Alvarez J.O. (1995) Nutrition, tooth development and dental caries. *American Journal of Clinical Nutrition* **61**(Suppl.), 410S–416S.

American Academy of Pediatric Dentistry. (1989) *Dental Health Objectives for Children for the Year 2000*. American Academy of Pediatric Dentistry: Chicago, IL.

British Society of Pediatric Dentistry. (1992) A policy document on sugars and the dental health of children. *International Journal of Paediatric Dentistry* **2**, 177–180.

Chen M. (1995) Oral health of disadvantaged populations. In: *Disease Prevention and Oral Health Promotion Socio-Dental Sciences in Action* (eds L.K. Cohen & Gift H.C.), pp. 153–196. Munksgaard: Copenhagen.

DePaola D.P., Faine M.P. & Palmer C. (1999) Nutrition in relation to dental medicine. In: *Modern Nutrition in Health and Disease* (eds E.M. Shils, J.A. Olson, M. Shike & A.C. Ross), 9th edn, pp. 1099–1124. Williams & Wilkins: Philadelphia, PA.

DePaola D.P., Mobley C. & Touger-Decker R. (2002) Nutrition and oral medicine. In: *Handbook of Nutrition and Food* (ed. C.D. Berdanier), pp. 1113–1134. CRC Press LLC: Boca Raton, FL.

Department of Health. (1994) *National Oral Health Survey South Africa 1988/89*. Government Printer: Pretoria.

Enwonwu C.O. (1995) Interface of malnutrition and periodontal diseases. *American Journal of Clinical Nutrition* **61**(Suppl.), 430S–436S.

Fass E.N. (1962) Is bottle feeding of milk a factor in dental caries? *Journal of Dentistry Child* **29**, 245–251.

Featherstone J.D.B. (2000) The science and practice of caries prevention. *Journal of the American Dental Association* **131**, 887–899.

Garcia-Godoy F., Mobley C.C., Jones D.L. & Mays M.H. (1995) *Caries and Feeding Patterns in South Texas Pre-School Children*. Final Report. University of Texas Health Science Centre: San Antonio, TX.

Gratrix D. & Holloway P.J. (1994) Factors of deprivation associated with caries in young children. *Community Dental Health* **11**, 66–70.

Greenspan J.S., Kahn A.J., Marshall S.J., Newbrun E. & Plesh O. (1995) Current and future prospects for oral health science and technology. *Journal of Dental Education* **59**, 149–167.

Grossi S.G. & Genco R.J. (1998) Periodontal disease and diabetes mellitus: a two-way relationship. *Annals of Periodontology* **3**, 51–61.

Harding M.A., Whelton H., O'Mullane D.M. & Cronin M. (2003) Dental erosion in 5-year-old Irish school children and associated factors. *Community Dental Health* **20**, 165–170.

Harley K. (1999) Tooth wear in child and youth. *British Dental Journal* **186**, 492–496.

Hausen H. (1998) Caries prediction – state of the art. *Community Dentistry and Oral Epidemiology* **25**, 87–96.

Hinds K. & Gregory J. (1995) *National Diet and Nutrition Survey: Children Aged 1 (1/2) to 4 (1/2) Years Office of Population Census and Surveys*. HMSO: London.

Holt R.D. & Downer M.C. (1996) Caries in pre-school children in Camden 1993/94. *British Dentistry Journal* **181**, 405–410.

Ismail A.I., Burt B.A. & Eklund S.A. (1984) The cariogenicity of soft drinks in the United States. *Journal of the American Dental Association* **109**, 241–245.

Jamel H.A., Sheiham A., Watt R.G. & Cowell C.R. (1997) Sweet preference, consumption of sweet tea and dental caries: studies in urban and rural Iraqi populations. *International Dental Journal* **47**, 213–217.

Johnsen D.C., Schechner T.G. & Gerstenmaier J.H. (1987) Proportional changes in caries patterns from early to late primary dentition. *Journal of Public Health Dentistry* **47**, 5–9.

Jones D.B., Schlife C.M. & Phipps K.R. (1995) An oral health survey of headstart children in Alaska: oral health status, treatment needs and cost of treatment. *Journal of Public Health Dentistry* **52**, 86–93.

Kaste L.M., Marianos D., Chang R. & Phipps K.R. (1992) The assessment of nursing caries and its relationship to high caries in the permanent dentition. *Journal of Public Health Dentistry* **52**, 64–68.

König K.G. (2000) Diet and oral health. *International Dental Journal* **50**, 162–174.

Krall E. (2001) The periodontal-systemic condition: implications for treatment of patients with osteoporosis and periodontal disease. *Annals of Periodontology* **6**, 209–213.

Kunzel W. & Fischer T. (1997) Rise and fall of caries prevalence in German towns with different fluoride concentrations in drinking water. *Caries Research* **31**, 166–173.

Litt M., Reisine S. & Tinanoff N. (1995) Multidimensional causal model of dental caries development in low-income preschool children. *Public Health Reports* **110**, 607–617.

Low W., Tan S. & Schwartz S. (1999) The effect of severe caries on the quality of life in young children. *Pediatric Dentistry* **21**, 325–326.

Luo Y., Zeng X.J., Du M.Q. & Bedi R. (2005) The prevalence of dental erosion in preschool children. *Journal of Dentistry* **33**, 115–121.

Malik M.I., Holt R.D. & Bedi R. (2001) The relationship between erosion, caries and rampant caries and dietary habits in preschool children in Saudi Arabia. *International Journal of Paediatric Dentistry* **11**, 430–439.

Mattee M.I.N., Van't Hof M.A., Maselle S.Y., Mikx F.H.M. & Van Palenstein W.H. (1994) Nursing caries, linear hypoplasia and nursing and weaning habits in Tanzanian infants. *Community Dentistry and Oral Epidemiology* **22**, 289–293.

Millward A., Shaw L. & Smith A. (1994) Dental erosion in four year old children from differing socio-economic backgrounds. *Journal of Dentistry for Children* **61**, 263–266.

Milnes A.R. (1996) Description and epidemiology of nursing caries. *Journal of Public Health Dentistry* **56**, 38–50.

Nainar S.M. & Mohummed S. (2004) Diet counseling during the infant oral health visit. *Pediatric Dentistry* **26**, 459–462.

Nishida M., Grossi S.G., Dunford R.G., Ho A.W., Trevisan M. & Genco R.J. (2000) Dietary vitamin C and the risk for periodontal disease. *Journal of Periodontology* **71**, 1215–1223.

O'Sullivan D.M. & Tinanoff N. (1993) Maxillary anterior caries associated with increased caries risk in other primary teeth. *Journal of Dental Research* **72**, 1577–1580.

O'Sullivan D.M. & Tinanoff N. (1996) The association with early dental caries patterns in preschool children with caries incidence. *Journal of Public Health Dentistry* **56**, 81–83.

Papas A.S., Joshi A., Palmer C.A., Giunta J.L. & Dwyer J.T. (1995) Relationship between diet and root caries. *American Journal of Clinical Nutrition* **61**(Suppl.), 423S–429S.

Parry J., Shaw L., Arnaud M.J. & Smith A.J. (2001) Investigation of mineral waters and soft drinks in relation to dental erosion. *Journal of Oral Rehabilitation* **28**, 766–772.

Petersen P.E. (2003) *The World Oral Health Report 2003. Continuous Improvement of Oral Health in the 21st Century – the Approach the WHO Oral Programme.* WHO: Geneva.

Pine C.M. (1997) Introduction, principles and practice of public health. In: *Community Oral Health* (ed. C.M. Pine), pp. 1–9. Butterworth-Heinemann: Oxford.

Pizzo G., Piscopo M.R., Pizzo I. & Giuliana G. (2007) Community water fluoridation and caries prevention: a critical review. *Clinical Oral Investigation* e-publication. DOI 10.1007/s00784-007-0111-6.

Psoter W.J., Reid B.C. & Katz R.V. (2005) Malnutrition and dental caries: a review of the literature. *Caries Research* **39**, 441–447.

Ripa L.W. (1988) Nursing caries: a comprehensive review. *Pediatric Dentistry* **10**, 268–282.

Sayegh A., Dini E.L., Holt R.D. & Bedi R. (2005) Oral health, socio-demographic factors, dietary and oral hygiene practices in Jordanian children. *Journal of Dentistry* **33**, 379–388.

Scheutzel P. (1996) Etiology of dental erosion – intrinsic factors. *European Journal of Oral Sciences* **104**, 178–190.

Seow W.K. (1998) Biological mechanisms of early childhood caries. *Community Dentistry and Oral Epidemiology* **26**(Suppl.), 8–27.

Shaw L., Weatherill S. & Smith A. (1998) Tooth wear in children: an investigation of aetiolical factors in children with cerebral palsy and gastroesophageal reflux. *Journal of Dentistry for Children* **65**, 484–486.

Sheiham A. (1987) Sucrose and dental caries. *Nutrition and Health* **5**, 25–29.

Sheiham A. (1991) Why sugar consumption should be below 15 kg per person per year in industrialized countries: the dental evidence. *British Dental Journal* **171**, 63–65.

Sheiham A. (2001) Dietary effects on dental diseases. *Public Health Nutrition* **4**, 569–591.

Sheiham A. & Watt R.G. (2000) The common risk factor approach: a rational basis for promoting health. *Community Dentistry and Oral Epidemiology* **28**, 399–406.

Stecksen-Blicks C. & Holm A.-K. (1995) Dental caries, tooth trauma, malocclusion, fluoride usage, toothbrushing and dietary habits in 4-year-old Swedish children: changes between 1967 and 1992. *International Journal of Paediatric Dentistry* **5**, 143–148.

Steyn N.P., Myburgh N.M. & Nel J.H. (2003) Evidence to support a food-based dietary guideline on sugar consumption in South Africa. *Bulletin of the World Health Organization* **81**, 599–608.

Takahashi K. (1961) Statistical study on caries incidence in the first molar in relation to amount of sugar consumed. *Bulletin of the Tokyo Dental College* **2**, 44–57.

Tinanoff N. & O'Sullivan D.M. (1997) Early childhood caries: overview and recent findings. *Pediatric Dentistry* **19**, 12–16.

Tinanoff N. & Palmer C.A. (2003) Dietary determinants of dental caries and dietary recommendations for preschool children. *Journal of Public Health Dentistry* **60**, 197–206.

Touger-Decker R. & Gilbride J.A. (1997) Nutrition education of dental students and professionals. *Topics in Clinical Nutrition* **12**, 23–32.

US Department of Health and Human Services. (2000) *Oral Health in America: A Report to the Surgeon General*. US Department of Health and Human Services, National Institute of Dental and Cranio-facial Research, National Institutes of Health: Rockville, MD.

van Palenstein Helderman W.H., Soe W. & van't Hof M.A. (2006) Risk factors of early childhood caries in a Southeast Asian population. *Journal of Dental Research* **85**, 85–88.

van Wyk P.J., Kroon J. & Holtshousen W.S. (2001) Cost evaluation for the implementation of water fluoridation in Gauteng. *South Africa Dental Journal* **56**, 71–76.

Van Wyk P.J., Louw A.J. & du Plessis J.B. (2004) Caries status and treatment needs in South Africa: report of the 1999–2002 National Children's Oral Health Survey. *South Africa Dental Journal* **59**, 239–242.

Weinstein P. (1998) Public health issues in early childhood caries. *Community Dentistry and Oral Epidemiology* **26**(1 Suppl.), 84–90.

Wendt L.-K., Hallonsten A.-L., Koch G. & Birhed D. (1996) Analysis of caries related factors in infants and toddlers living in Sweden. *Acta Odontologica Scandinavica* **54**, 131–137.

WHO/FAO. (2003) *Diet, Nutrition and the Prevention of Chronic Diseases Report of a Joint WHO/FAO Expert Consultation*. World Health Organisation: Geneva. WHO Tech Report Series No. 919.

Ye W., Feng X.P. & Liu Y.L. (1999) Epidemiological study of the risk factors of rampant caries in Shanghai children. *Chinese Journal of Dental Research* **2**, 58–92.

Zero D.T. (1996) Etiology of dental erosion – extrinsic factors. *European Journal of Oral Sciences* **104**, 162–177.