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ORIGINAL ARTICLE

Tooth wear in the deciduous dentition of 5–7-year-old children: risk factors

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Abstract This study was conducted to investigate the distribution and severity of tooth wear in deciduous dentition and its relationship with possible risk factors. A stratified cluster sample of 243 5–7-year-old children was examined using the tooth wear index of Smith and Knight, and their exposure to intrinsic and extrinsic risk factors was retrospectively investigated through a structured questionnaire. The severity of wear was quantitatively estimated by the number of surfaces with affected dentine and by the cumulative score of the sextants, based on the Basic Erosive Wear Examination scoring system. Only 1.6% of the children were tooth wear free, whereas 45.6% had moderate to severe wear involving dentine. Maxillary canines were the most affected teeth (83.2%), and occlusal/incisal the most affected surfaces (52.7%). The likelihood of tooth wear involving dentine was greater in boys than girls (OR=1.72), in immigrants than in Greeks (OR=1.93), and in 6- and 7-year olds than in 5-year olds (OR=2.78 to 2.93). After adjustment for age, gender, and nationality, exposure to several dietary factors and especially to soft drinks was found to significantly affect the prevalence (OR=1.27) and the severity of tooth wear. Every additional serving/week of consumption of soft drinks increases the number of surfaces with dentine affected by 0.03 per year ($p<0.05$) and the cumulative score of sextants by 0.04 ($p<0.05$). The cluster of children with the higher prevalence and severity of tooth wear had an average exposure to soft drinks of 10 servings/week for a duration of 4 years. The cumulative score of sextants was better predicted by the assessed risk factors, in comparison with the number of surfaces with affected dentine. Tooth wear is a common condition in children, related both to the physiological process of aging of dentition and to the erosive effect of dietary factors. Strategies to reduce the intake of soft drinks in children are expected to have multiple benefits preventing tooth wear in childhood and in later life, as well as many other general and oral health diseases.

Keywords Tooth wear · Erosion · Deciduous dentition · Risk factors · Retrospective design

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Introduction

Tooth wear is a multifactorial etiology process characterized by progressive loss of hard dental tissues. The causes of tooth wear are considered to be erosion, attrition, and abrasion—with erosion being associated with the chemical dissolution of teeth by acids other than those produced by bacteria, attrition with wear due to tooth-to-tooth contact, and abrasion with wear by physical means other than teeth [1]. Attrition affects the proximal and interocclusal contact sites of the teeth, whereas most of their surfaces are susceptible to wear by abrasion and erosion. As more than one of the causal factors usually coexist and dynamically interact in the oral environment, the lesions are combined results with usually no causative-specific clinical appearance or distribution.

Tooth wear is a common condition in developed societies that affects people of all ages. Since the contribution of erosion to tooth wear is thought to be increasing, several assessment tools have been proposed for its measurement and for differentiating erosive lesions from

the other tooth wear processes using a variety of criteria like location, morphological characteristics of the lesion, optical features of the enamel, tooth tissues involved, and amount of hard tissue lost [2–7]. However, the indices currently available appear to measure tooth wear and not erosion specifically, while the use of different indices in the various studies makes the comparison of their results difficult.

Several studies have reported that tooth wear is common in the deciduous dentition and that it may be more severe than in the permanent dentition. In these studies, the prevalence of tooth wear ranged from 30% to 100% of the children examined and from 11% to 80% of the teeth examined [8–18]. The higher susceptibility of the deciduous dentition to tooth wear has rather been attributed to the reduced thickness of the enamel than to its greater solubility in acid [19].

Although there have been a large number of studies concerning the prevalence of tooth wear in children during the last 20 years, only a few studies have related tooth wear in deciduous dentition to possible causative factors. Some of these studies indicated association of acidic drink consumption with tooth wear on palatal surfaces of primary teeth [10–12, 14–18, 20]. There is also scarce clinical evidence concerning the effect of biological and behavioral risk factors on the development and severity of tooth wear in deciduous dentition [21]. The purposes of the present study were to assess the distribution and severity of tooth wear in a sample of 5–7-year-old children living in the city of Piraeus, Greece and to investigate retrospectively the effect of exposure to several erosive and abrasive risk factors.

Material and methods

The reference population comprised children aged 5–7 years attending primary schools and kindergartens of the urban zone of Piraeus. The study was conducted in May 2007, within the framework of the 2006–2007 Dental Preventive Program in Primary Educational Settings of the prefecture of Piraeus. Official permission for the program was obtained by the responsible authority.

After stratification of the schools according to the average household income at postcode area level, nine schools were randomly selected to participate in the study, evenly representing the income strata. The children meeting the age criteria (262 children in total) were approached, and 243 of them (92.7%) returned a written consent from their parents to participate in the study. The children were examined in a fully equipped mobile dental unit that visited the school settings. One examiner, graduate in community dentistry (TG), visually inspected all the deciduous teeth using a tongue retainer and air syringe for drying the surfaces. Tooth wear was recorded separately in lingual, buccal, and occlusal/incisal surfaces according to the criteria of tooth wear index (TWI) of Smith and Knight [4]:

Score 0 No loss of enamel surface characteristics
Score 1 Loss of enamel surface characteristics
Score 2 Loss of enamel with visible dentine on less than one third of the surface area
Score 3 Loss of enamel with visible dentine on more than one third of the surface area
Score 4 Complete loss of enamel, exposure of pulp, or secondary dentine

The examiner was trained in the use of the method through the booklet produced by the authors. Intra-examiner reproducibility was assessed with weighted Kappa statistic and was found 0.95 (95% CI 0.943–0.953).

In order to classify children according to the severity of tooth wear, their surface scores were grouped by type of tooth (incisors–canines–molars) and by type of surface (lingual–bucal–occlusal/incisal), considering for each group the maximum score recorded. These scores went through cluster analysis, which identified two clusters (Table 1) that combine 89.3% of the sample (217 out of 243 children). Cluster 1 included 113 children with no or mild tooth wear (TWI<2), and cluster 2 included 104 children with tooth wear involving dentine (TWI≥2). Therefore, the presence of exposed dentine on any tooth surface was used as the cutoff point for the binary analysis of tooth wear (the presence vs absence of wear involving dentine).

For the quantitative estimation of tooth wear per person, two variables were computed from the original data set: (1) the number of surfaces with exposed dentine and (2) the cumulative score of sextants (CS score), which is based on the scoring system (Basic Erosive Wear Examination, BEWE) proposed by Bartlett et al. [6]. According to this scoring system, the most severely affected tooth in each sextant is recorded, and the sum of scores is calculated. The BEWE uses a four-level score to record the severity of tooth wear (from 0 to 3), and therefore, the cumulative

Table 1 Cluster profiles for patterns of tooth wear

	Cluster 1 (n=113) Tooth wear involving dentine	Cluster 2 (n=104)	Total (n=243)
Incisors	0.0%	71.1%	34.4%
Canines	0.0%	64.4%	30.8%
Molars	0.0%	24.0%	11.3%
Occlusal surfaces	0.0%	95.2%	44.0%
Buccal surfaces	0.0%	10.6%	4.5%
Lingual surfaces	0.0%	10.6%	4.9%

score of sextants ranges from 0 to 18. On the other hand, the TWI uses a five-scale score (from 0 to 4). In order to have the BEWE range of scores, and since only two children in our sample had TWI score of 4, the grades 3 and 4 of the TWI were merged. For the purposes of this study, the cumulative score of sextants was calculated in two ways: once taking into account all the surfaces of the teeth and once excluding the incisal edges.

A 22-item questionnaire was administered to the parents of the children examined in order to investigate retrospectively their exposure to the following groups of factors related with tooth wear: (1) conditions related to gastric acid reflux (vomiting, gastroesophageal reflux, acid taste, dry mouth, asthma), (2) history of acidic medicine use (Fe, vitamin C, polyvitamin supplements, inhalers), (3) habits related to mechanical tooth wear (teeth crackling, nail gnawing, pencil beating, nuts beating), (4) swimming pool use, (5) tooth brushing frequency, and (6) history of dietary habits such as: (a) bottle feeding (cessation age, drinks used, nighttime use), (b) soft drinks consumption—the question included any kind of packed fruit and soda drinks (starting age, frequency of actual consumption, and preferred product), (c) fresh fruits consumption—the question included fruits and juices (starting age, frequency of actual consumption, and preferred fruit), and (d) frequent consumption of acidic foodstuff (salads, fruit candies, pickles, yoghurt). Information was also obtained on parents' education and occupation. All questions were closed (ticking boxes format), except of those concerning children's preference for soft drinks and fresh fruits and parents' occupation, which were open ended. Age, gender, and nationality were obtained from the school registers.

The risk factors of groups 1, 2, 3, 4, and 6d were coded as binary variables (no history vs history), and for each group of factors, the cumulative score of the exposure was also calculated. The risk factors of the other groups were coded as follows: (a) tooth brushing frequency—less than two times/day vs two or more times/day; (b) preferred soft drink—carbonated vs non-carbonated; and (c) preferred fresh fruit—acidic (citrus fruits, apples, and grapes) vs other fruits. The frequency of soft drink and fresh fruit consumption was coded in servings/week. The exposure of children to soft drinks and fresh fruits (separately and in combination) was also computed as the product of the years of consumption by the frequency of consumption (years servings/week).

As the diagnosis of tooth wear status was set at the time of the clinical examination and there was no previous information on children's exposure to the risk factors, the study meets the criteria of retrospective design. The data were processed and analyzed by means of the Statistical Package for the Social Sciences (SPSS version 16.0). Initial data analysis relied on descriptive statistics; subsequent, binary logistic regression analysis was used to assess the associations between risk factors and the prevalence of tooth wear. In addition, linear regression analysis was used to assess the strength of correlation of the exposure to risk factors with the quantitative estimators of tooth wear. In the above analyses, the effect of each risk factor was controlled for possible confounders through multivariate model. Finally, cluster analysis was attempted to confirm the association of the identified risk factors with the observed patterns of tooth wear.

Results

Of the 262 children invited to participate, 243 (92.7%) returned a consent form and were clinically examined. Their mean age was 6.37 years. One hundred and twenty-two (50.2%) of these children were boys and 121 (49.8%) girls, while 191 (78.6%) were Greeks and 52 (21.4%) immigrants, the vast majority of Albanian nationality. Of the 243 children examined, 198 (81.5%) returned a questionnaire. Nonresponders did not differ from responders regarding gender and tooth wear prevalence, but they differed significantly regarding their nationality (15.7% nonresponders among Greeks and 28.8% among immigrants, $p<0.02$).

Only 1.6% of the children were tooth wear free, 51.8% exhibited mild tooth wear in the enamel (maximum TWI=1), 41.6% moderate tooth wear involving dentine (maximum TWI=2), 4.1% severe tooth wear into the dentine (maximum TWI=3), and 0.8% severe tooth wear with pulp involvement (maximum TWI=4). The distribution and the severity of tooth wear on the occlusal, buccal, and lingual surfaces of the deciduous teeth are illustrated in Figs. 1, 2, and 3. The overall prevalence of tooth wear was greater in the maxilla than in the mandible. The most frequently affected teeth were the maxillary canines (83.2%), followed by the maxillary incisors (62.9%) and molars (35.5%). The most frequently affected surfaces were the occlusal/incisal (52.7%), followed by the buccal (4.6%) and lingual surfaces (2.56%). Tooth wear involving dentine (TWI score≥2) was mainly observed in the maxillary canines and incisors (20.5% and 16.0%, respectively) and in the occlusal/incisal surfaces (9.8%).

Table 2 presents the results of the multivariate logistic regression analysis for the significant sociodemographic factors affecting the prevalence of tooth wear involving dentine. The likelihood of tooth wear was greater in boys than in girls, in immigrants than in Greeks, and in 6- and 7-year olds than in 5-year olds. No significant associations were found regarding the socioeconomic status of children estimated by their parents' education and occupation, as well as between 6-year-old and 7-year-old children. Since

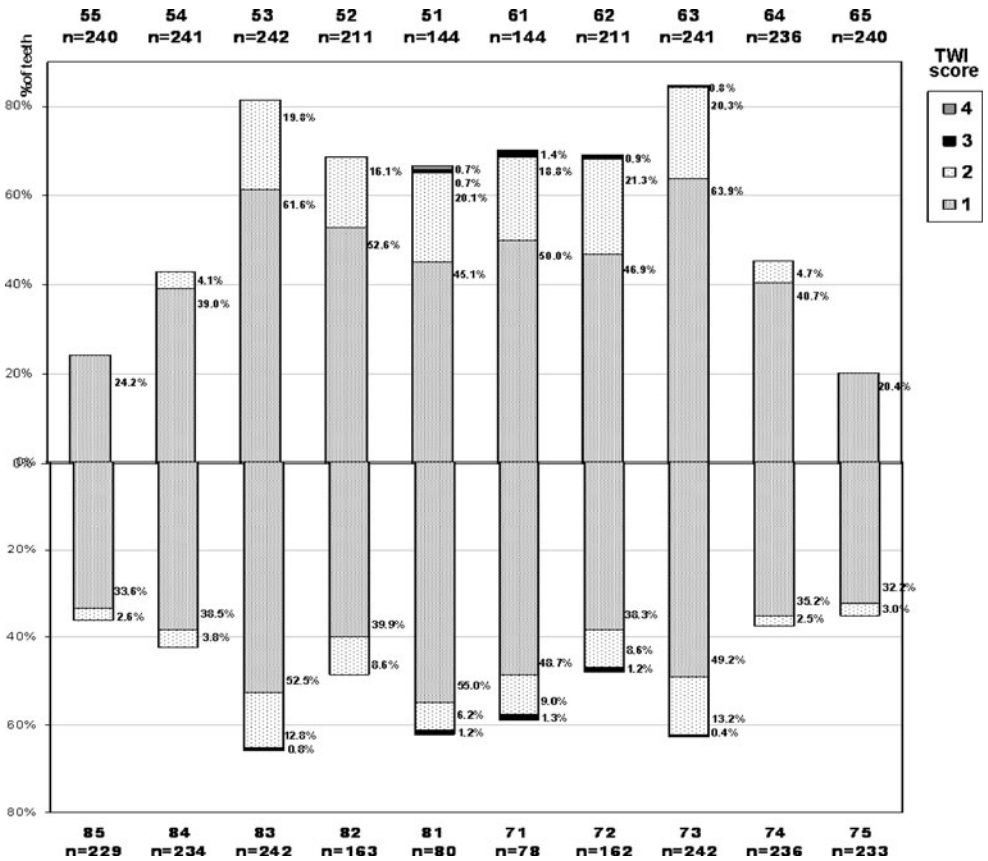

Fig. 1 Distribution of tooth wear on occlusal/incisal surfaces in 243 children aged 5–7 years

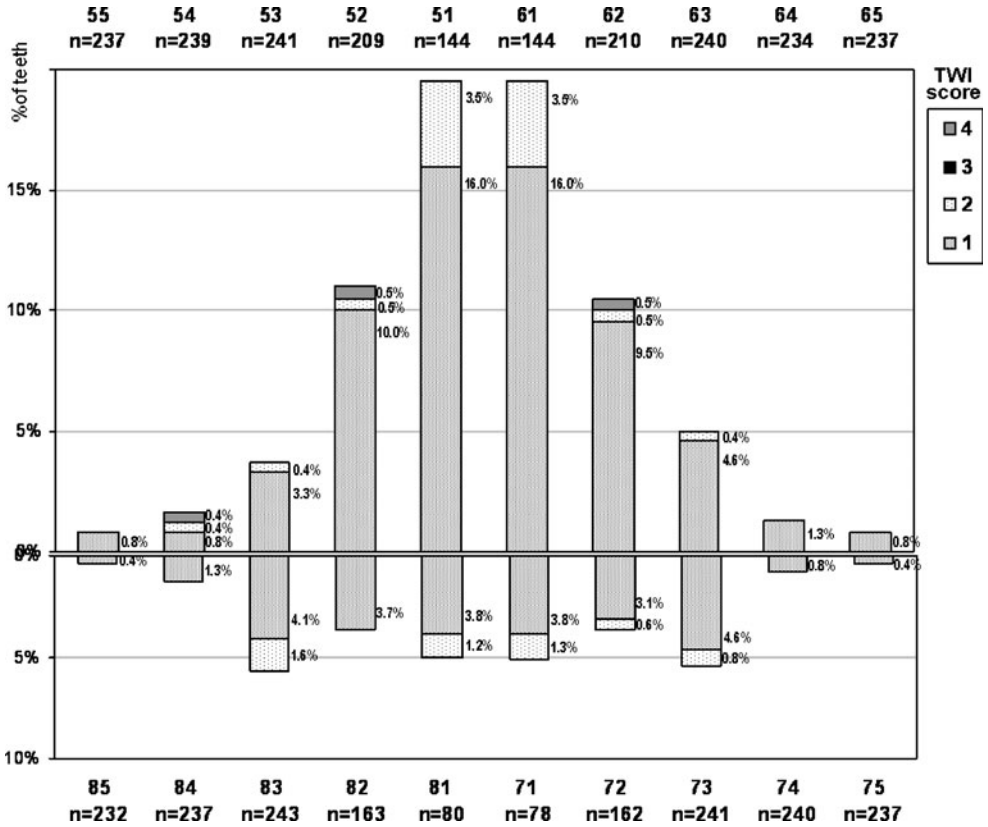

Fig. 2 Distribution of tooth wear on buccal/labial surfaces in 243 children aged 5–7 years

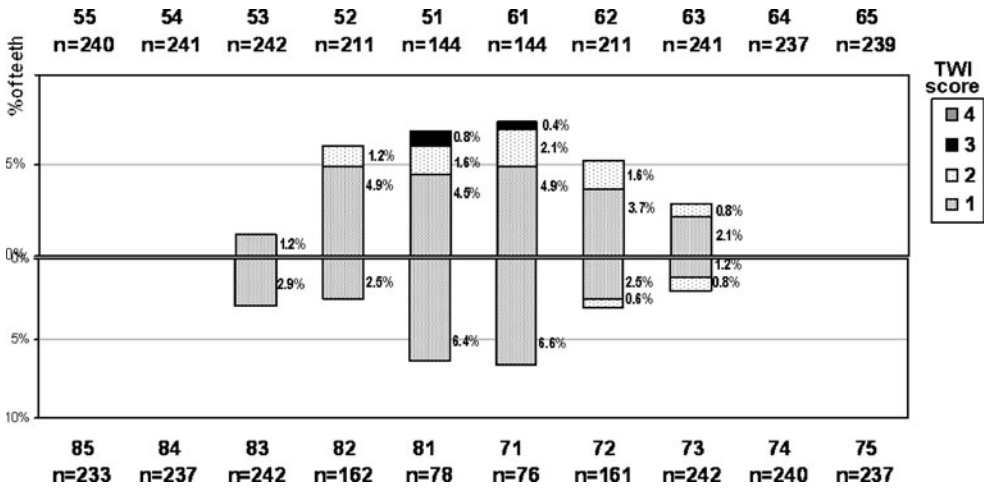

Fig. 3 Distribution of tooth wear on lingual/palatal surfaces in 243 children aged 5–7 years

age, gender, and nationality were significantly and independently correlated with tooth wear, they were controlled as possible confounders in all further analyses.

Table 3 presents the prevalence of tooth wear involving the dentine according to the presence or absence of risk factors, as well as the results of the multivariate analysis. As can be seen, most of the significant associations are related to soft drinks. The years of consumption, the frequency of consumption, and the total exposure to soft drinks increased the chances for tooth wear involving dentine. In addition, although no significant correlations were found regarding fresh fruit consumption, the cumulative exposure to soft drinks and fresh fruits either as servings per week or as total exposure was significantly associated with tooth wear. A significant association was also found between frequent salad consumption and the presence of tooth wear into dentine. In all analyses, age and gender showed stable confounding effect, whereas nationality failed statistical significance in most cases. In addition, fresh fruit/juice consumption was correlated with soft drink consumption (r=0.249, p<0.001) and with frequent salad consumption (r_s=0.297, p<0.001) (data not shown).

Table 2 Multivariate logistic regression analysis for the sociodemographic factors significantly affecting tooth wear prevalence (n=243)

Sociodemographic variables	OR[a]	95% CI
Gender (boys vs girls)	1.72	1.01–2.91
Nationality (immigrants vs Greeks)	1.93	1.01–3.66
Age (6 vs 5 years)	2.93	1.26–6.79
Age (7 vs 5 years)	2.78	1.29–5.94
Constant	0.242	

[a] Multivariate logistic regression analysis for the independent effect of each factor. Dependent variable, presence vs absence of tooth wears involving dentine

The associations between the risk factors and the quantitative estimators of tooth wear (number of surfaces with exposed dentine, CS score including all surfaces, and CS score excluding incisal edges) were examined using linear regression analysis and the significant results are presented in Table 4. Frequency of soft drink consumption, total exposure to soft drinks, total exposure to soft drinks and fresh fruits, as well as the cumulative score of acidic food frequent consumption, were correlated with both the number of severely affected surfaces and the CS scores. The duration of bottle feeding was correlated only with the number of severely affected surfaces, whereas the time of exposure to soft drinks, preference for carbonated soft drinks, frequency of consumption, and total exposure to fresh fruits/juices as well as soft drinks plus fresh fruit/juice frequency of consumption were correlated only with the CS scores. The cumulative score for the habits related to mechanical wear was significantly correlated with the CS score counting all the surfaces, but indicatively correlated with the CS score excluding the incisal edges. Through all the above multivariate analyses, gender retained a confounding effect, whereas nationality failed significance. Age had a confounding effect in the regression on CS scores but not in the regression on the number of surfaces with dentine affected.

The cluster analysis for the distribution of the risk factors in association with tooth wear prevalence and severity (Table 5) identified two clusters including 155 children (78% of the total sample). In cluster 1 that included 43 children, the prevalence of tooth wear involving dentine was 63%, and the mean CS score (counting all surfaces) was 5.26. This group consumed soft drinks for an average of 4 years and in an average frequency of 10 servings/week. The prevalence of tooth wear involving dentine in cluster 2 that included 112 children was 45% and the mean CS score was 4.36. These children had an average exposure to soft drinks of 2.6 years and an average frequency of consumption

Table 3 Logistic regression analysis results of risk factors affecting the prevalence of tooth wear (n=198)

	Tooth wear involving dentine		OR (95% CI)[b]
	Presence[a] (n=95)	Absence[a] (n=103)	
Risk factors			
Cumulative score for exposure to gastric acid (0–5)	0.35 (0.59)	0.29 (0.59)	1.14 (0.67–1.92)
Any history of exposure to gastric acid (n=51)	29.5%	22.3%	1.21 (0.61–2.39)
Frequent vomiting (n=14)	5.3%	8.9%	0.47 (0.15–1.54)
Gastroesophageal reflux (n=12)	8.4%	3.9%	1.94 (0.92–4.11)
Acidic taste (n=1)	1.1%	0.0%	Non-countable
Dry mouth (n=1)	1.1%	0.0%	Non-countable
Asthma/chronic respiratory disease (n=35)	18.9%	16.5%	0.88 (0.41–1.90)
Cumulative score for exposure to acidic medicine (0–4)	0.87 (0.91)	0.78 (0.75)	1.08 (0.76–1.54)
Any history of acidic medicine use (n=123)	62.1%	62.1%	0.91 (0.50–1.65)
Fe supplement (n=47)	25.3%	22.3%	1.36 (0.68–2.73)
Vitamin C (n=11)	6.3%	4.9%	1.16 (0.33–4.15)
Polyvitamin (n=23)	15.8%	7.8%	2.25 (0.87–5.82)
Inhalers (n=82)	40.0%	42.7%	0.76 (0.41–1.39)
Cumulative score for exposure to mechanical wear (0–4)	0.67 (0.80)	0.62 (0.79)	1.03 (0.72–1.48)
Any history of exposure to mechanical wear (n=92)	48.4%	44.7%	1.10 (0.62–1.98)
Teeth crackling (n=40)	23.2%	17.5%	1.22 (0.59–2.52)
Nail gnawing (n=41)	20.0%	21.4%	0.97 (0.48–1.99)
Pencil beating (n=29)	14.7%	14.6%	1.03 (0.46–2.34)
Nuts grinding (n=18)	9.5%	8.7%	0.86 (0.32–2.32)
Swimming pool use (n=32)	17.9%	14.6%	1.26 (0.57–2.79)
Toothbrushing ≥2 times/day (n=39)	20.0%	19.4%	0.95 (0.46–1.95)
Dietary factors			
Bottle feeding exposure time (months)	36.0 (19.1)	38.0 (20.1)	0.99 (0.98–1.01)
Bottle feeding during bedtime (n=106)	55.4%	53.9%	1.01 (0.60–1.96)
Milk feeding by bottle during bedtime (n=95)	47.4%	48.5%	0.82 (0.45–1.48)
Fresh juices feeding by bottle during bedtime(n=3)	3.2%	0.0%	Non-countable
Soft drinks feeding by bottle during bedtime (n=2)	2.1%	0.0%	Non-countable
Tea feeding by bottle during bedtime (n=15)	6.3%	8.7%	0.59 (0.19–1.77)
Preference for carbonated soft drinks (n=72)	51.3%	41.6%	1.34 (0.69–2.61)
Soft drinks exposure time (years)	3.1 (1.4)	2.5 (1.5)	*1.27* (*1.04–1.56*)
Soft drinks frequency of consumption (servings/week)	6.0 (4.6)	4.3 (4.1)	*1.09* (*1.02–1.17*)
Soft drinks total exposure (years servings/week)	21.8 (22.7)	13.7 (15.3)	*1.02* (*1.00–1.04*)
Preference for acidic fresh fruits/juices (n=122)	65.3%	58.3%	1.38 (0.76–2.53)
Fresh fruits/juices exposure time (years)	5.0 (1.3)	4.9 (1.2)	0.82 (0.61–1.12)
Fresh fruits/juices frequency of consumption (servings/week)	7.9 (4.2)	7.4 (4.0)	1.05 (0.97–1.12)
Fresh fruits/juices total exposure (years servings/week)	39.7 (22.1)	36.3 (20.2)	1.01 (0.99–1.02)
Soft drink+fresh fruits frequency of consumption (servings/week)	13.7 (7.3)	11.8 (6.0)	*1.05* (*1.01–1.10*)
Soft drinks+fresh fruits exposure (years servings/week)	50.0 (28.1)	61.3 (37.3)	*1.01* (*1.00–1.02*)
Cumulative frequent acidic foods consumption (0–4)	1.69 (0.88)	1.50 (0.79)	1.37 (0.96–1.94)
Any acidic foods frequent consumed (n=190)	95.8%	96.1%	1.34 (0.31–5.84)
Salads (n=112)	65.3%	48.5%	*2.06* (*1.14–3.72*)
Fruit candies (n=30)	16.8%	13.6%	1.19 (0.54–2.68)
Pickles (n=22)	10.5%	11.7%	1.02 (0.40–2.56)
Yoghurt (n=151)	76.8%	75.7%	1.10 (0.60–2.17)

[a] Mean (SD) for the continuous variables and percent in risk group for binary variables

[b] Multivariate logistic regression analysis, controlling for age, gender, and nationality; dependent variable, tooth wear in dentine; statistically significant results are rendered in italics

Table 4 Linear regression analysis of risk factors affecting tooth wear severity (n=198)

	Dependent variable: no. of surfaces with tooth wear in dentine		Dependent variable: CS score (counting all surfaces)		Dependent variable: CS score (incisal edges excluded)	
	Unstandardized β	p value[a]	Unstandardized β	p value[a]	Unstandardized β	p value[a]
Risk factors						
Cumulative score for exposure to mechanical forces	−0.026	0.457	0.570	*0.009*	0.315	0.081
Dietary factors						
Bottle feeding exposure time (months)	−0.024	*0.018*	−0.002	0.891	−0.004	0.620
Soft drinks exposure time (years)	0.221	0.100	0.308	*0.010*	0.199	*0.044*
Soft drinks juices frequency of consumption (servings/week)	0.098	*0.026*	0.161[b]	*0.012*	0.120[b]	*0.021*
Soft drinks total exposure (years servings/week)	0.031	*0.002*	0.037[b]	*0.019*	0.026[b]	*0.040*
Preference for carbonated soft drinks	0.324	0.441	0.662	*0.010*	0633	*0.038*
Soft drinks consumption at evening	0.801	0.669	3.467	*0.048*	1.494	0.295
Fresh fruits/juices juices frequency of consumption (servings/week)	0.060	0.214	0.108	*0.012*	0.104	*0.003*
Fresh fruits/juices total exposure (years servings/week)	0.009	0.326	0.018	*0.027*	0.018	*0.007*
Preference for acidic fruits	0.714	0.073	0.471	0.191	0.506	0.084
Soft drinks+fresh fruits/juices frequency of consumption (servings/week)	0.056	0.058	0.067	*0.009*	0.057	*0.007*
Soft drinks+fresh fruits/juices exposure (years servings/week)	0.013	*0.028*	0.013	*0.011*	0.012	*0.008*
Cumulative score of acidic foods frequent consumption	0.460	*0.050*	0.468	*0.025*	0.153	0.373
Frequent salad consumption	0.124	0.752	0.708	*0.044*	0.354	0.219

[a] Multivariate linear regression analysis, controlling for age, gender, and nationality; statistically significant results are rendered in italics

[b] Stratified analysis only for age group <7 years

of 4 servings/week. Cluster 1 had double average consumption of fresh fruits/juices than cluster 2 (12 vs 6 servings/week) and 1.5 times higher reported salad consumption (75% vs 49%).

Discussion

The results of this study suggest that tooth wear is very common in the deciduous dentition at the age of 5–7 years; only 1.6% of the sample was tooth wear free. These findings generally agree with those of previous studies. For example, Warren et al. [17], in a study of 355 American children with a mean age of 4.7 years, reported that no child was completely free of the condition, while Hugoson et al., [22] in a study of 527 Swedish children, found that only 19% of the 5-year olds had no or slight incisal or occlusal wear. However, the percentage of children showing severe wear (score 3 or 4) found in the present study is much lower (4.9%) than that reported by Warren et al. [17] (15.8%) and Ayers et al. [18] (27.9%), while the percentage of children showing moderate wear (41.6%) is much higher than that observed by Hugoson et al. [22] (17.0%). Such differences could be attributed to the fact that surveys are carried out by different examiners, under varying field conditions, with different sampling methods and slightly different methods of recording. But they may also reflect different exposure to dietary, biological, and behavioral risk factors.

The analysis of data concerning the distribution of tooth wear within the dentition showed that it was more common in the maxillary than in the mandible, in the posterior than in the anterior teeth, and in the occlusal/incisal than in the buccal or lingual surfaces. Previous studies have found similar patterns of distribution of tooth wear [11, 17, 20, 22].

In the present study, the prevalence of tooth wear increased with age, similar with other previous studies [8, 12, 18, 22–24]. The 6- and 7-year olds were three times more likely to have tooth wear into dentine than the 5-year olds. However, no statistically significant difference was observed between the 6- and 7-year olds, probably due to the gradual transition from the deciduous to the early stage of mixed dentition. Nevertheless, the effect of age was

Table 5 Cluster profiles for prevalence and severity of tooth wear and risk factors (n=198)

	Cluster 1 (n=43)	Cluster 2 (n=112)	Total (n=198)
Continuous variables (mean)			
CS score (counting all surfaces)	5.26	4.36	4.54
Soft drinks exposure time (years)	4.02	2.62	2.81
Soft drinks frequency of consumption (servings/week)	10.09	3.85	5.11
Soft drinks total exposure (years servings/week)	40.67	10.38	17.57
Fresh fruits/juices frequency of consumption (servings/week)	11.86	5.74	7.63
Fresh fruits/juices total exposure	63.42	28.41	37.92
Soft drinks+fresh fruits/juices frequency of consumption (servings/week)	21.70	9.58	12.70
Soft drinks+fresh fruits/juices total exposure (years servings/week)	100.60	38.75	55.39
Bottle feeding exposure time (months)	31.05	40.00	37.07
Categorical variables (% in cluster)			
Tooth wear involving dentine	62.8%	45.5%	48.0%
Nationality (immigrants)	32.5%	13.4%	18.7%
Frequent salad consumption	74.4%	49.1%	56.6%
Preference of carbonated drinks	53.5%	43.7%	46.5%
Preference for acidic fruits	72.1%	59.8%	61.6%

controlled with each risk factor and retained statistical significance in most cases. Therefore, this effect could be attributed to the physiological process of the aging of the dentition and might be considered as a proxy for this effect. Interestingly, age was significantly correlated with the CS scores (which evaluate the whole range of the clinical manifestations of tooth wear), but not with the number of surfaces with dentine affected (that evaluates the advanced stages of the disease). This finding could possibly reflect two different rates of tooth wear progress: a low speed progress into the enamel and a high speed progress into the dentine.

Gender was significantly correlated with tooth wear in the present study, with boys being more affected than girls. This is in agreement with the study of Wiegand et al. [12], but most studies assessing tooth wear in deciduous dentition have not found differences between genders [10, 11, 14–18, 20, 22, 24]. Previous studies in adolescents reported males having significantly greater tooth wear than females and attributed this difference to the stronger biting forces and greater masticatory muscle mass of males [25, 26].

No association was found between tooth wear and the socioeconomic status of children estimated by their parents' education and occupation. In previous studies, tooth wear in deciduous dentition has been ambivalently correlated with socioeconomic class. Harding et al. [15], as well as Kazoulis et al. [10], found higher rates of tooth wear in families with low socioeconomic status, whereas Luo et al. [14], as well as Mangueira et al. [9], found higher rates of tooth wear in families with high educational level and in children who attended private schools. However, both directions of correlation are interpreted by the underlying linkage of socioeconomic class with lifestyle factors that are related with more frequent consumption of acidic foods and especially carbonated drinks.

Among the conditions related to mechanical tooth wear assessed in the present study, no one was individually correlated with tooth wear. Bruxism, which is a strong risk factor for occlusal tooth wear, failed to show significant correlation, probably due to the fact that parents are not aware of the presence of this condition in their children and, therefore, underreport it [27, 28]. The finding that the cumulative score of the above conditions was strongly associated with the CS score counting all the surfaces but only indicatively associated with the CS score excluding the incisal edges can be explained by the fact that the occlusal surfaces are less affected by tooth wear than the incisal ones.

No associations were found between tooth wear and exposure to gastric acid, use of acidic medicines, swimming pool use, and frequency of toothbrushing. On the contrary, the dietary factors, and especially the consumption of soft drinks, were shown to have a significant impact on tooth wear development. Every additional year of exposure to soft drinks increased the CS scores by 0.199–0.308. Every additional serving of soft drinks per week increased the CS scores by 0.026–0.037 and the number of surfaces with dentine exposure by 0.031 every year. The preference for carbonated soft drinks increased the CS scores by 0.633–0.662, while the habit of consumption of soft drinks before bedtime increased the CS score (all surfaces) by 3.5. Other dietary factors that were found to have a significant association with tooth wear included the consumption of

fresh fruits/juices alone or in combination with soft drinks, the frequent consumption of salads, and the duration of bottle feeding. Every additional serving/week of fresh fruits/juices increased the CS scores by 0.018 every year. The frequent consumption of salads increased the CS score (all surfaces) by 0.708, and for every additional of the acidic foods (fruit candies, pickles, yoghurt) frequently consumed, the score increased by 0.468. Salads and fresh fruits, except of the possible erosive effect, may have a mechanical effect, as a component of a rough diet, demanding more vigorous masticatory forces.

The duration of bottle feeding has a significant inverse correlation with the number of surfaces affected by tooth wear extending to the dentine; the longer the duration of bottle feeding, the fewer surfaces affected. Actually, one out of six children in this study was still using the feeding bottle. The prolonged use of feeding bottle could be an indicator of low masticatory activity of the children, a factor that is linked to the decreasing severity of occlusal wear, as indicated by the secular trends [15, 29, 30].

Despite the laboratory evidence of the erosive potential of several dietary factors on dental hard tissues [31], few previous studies on children with deciduous dentition succeeded to reveal any clinical effect, especially a quantitative (dose-related) one. Harding et al. [15] found higher odds ratios of erosive tooth wear in the group of frequent consumers of carbonated and fruit drinks in a study among 202 5-year-old Irish children, and Luo et al. [14] found higher odds ratio of tooth wear in the group of children taking fruit drinks by feeding bottle in bedtime in a study among 1,949 Chinese children 3–5 years old. O'Sullivan and Curzon [32], in a case–control study among 103 British 2–7-year olds, found significant association of the prevalence of erosive tooth wear with the frequency of consumption of acidic beverages and with the habits of swishing and holding the fluid in the mouth. Murakami et al. [33], in a sample of 967 Brazilian children aged 3–4 years, found higher odds ratios of erosive tooth wear in the group that consumed soft drinks twice or more per day. Al-Majed et al. [16], in a group of 46 5–6-year-old boys in Saudi Arabia with pronounced tooth wear (involving dentine and pulp) on the palatal surfaces of maxillary incisors, found significant relation between the number of affected surfaces and the consumption of carbonated drinks in bedtime. Millward et al. [20], in a group of 101 children aged 4–16 years, assessing both deciduous and permanent dentition, found significant association of tooth wear severity (no/mild–moderate–severe) with the frequency of carbonated drinks and fruit drinks consumption and with fruit-based drinks consumption at bedtime. However, other investigators have not found any relationship between tooth wear and erosive dietary factors [11, 12, 17, 34].

The results of the present study are evident of the detrimental effect of the frequent and prolonged consumption of acidic drinks and foods on the prevalence and severity of tooth wear in the deciduous dentition. As a confirmation of the above, when all the significant risk factors identified in the present study were included in the cluster analysis, 76% of the total sample was combined to form two clusters: one cluster with high prevalence and severity of tooth wear associated with high exposure to risk factors and one cluster with lower prevalence and severity of tooth wear and lower exposure to risk factors. Even if the wear in the primary teeth does not require clinical intervention in most cases, it must not be overlooked. Longitudinal studies found that tooth wear in the deciduous dentition indicates a risk situation for wear in the permanent dentition, suggesting a common etiology [35, 36]. Thus, identifying children with tooth wear could help develop strategies to prevent it later in life.

Among the children investigated, the average consumption of soft and fruit drinks was 5 servings/week for a mean time of 2.75 years. One fourth of the children had an average of 10 servings/week, which corresponds to 1.5 servings/day, and a history of 4 years of consumption, which means that they started consumption at the mean age of 2.4 years. This level of consumption exceeds the dietary guidelines for the specific age group, which allow for up to 12–15% of the total daily energy intake from noncore foods, e.g., sweetened or high-fat foods (a range of 132–290 kcal/day, depending on the physical activity of the children) [37, 38]. The energy of a single packing of soft or fruit drink may be equal or greater than the total daily discretionary energy allowance. Furthermore, according to the results of a longitudinal study, sweetened drink consumption is anticipated to increase from preschool years through adolescence [39]. On the other hand, the mean consumption of fruit reported in the present study was 7.6 servings/week, which corresponds to 1 serving/day, when the dietary guidance advises for 3–4 servings/day [37]. In this study, the consumption of soft drinks was positively correlated with that of fresh fruit/juices. This finding, in combination with the previous remarks, may reflect a positive attitude of mothers toward the consumption of fruit drinks by their children. One study reported that mothers of toddlers hold misconceptions about the nutritional value of fruit drinks and their accounting risks for tooth diseases influenced by the claims used in the advertisements of these products [40]. Soft drinks are actually among the most intensively advertised products during children TV programs [41, 42], and their frequent consumption is also considered as a risk factor for childhood obesity [43] and dental caries in the primary teeth [44]. Therefore, strategies to reduce the consumption of

sweetened beverages in children could have multiple benefits for children's general and oral health.

The results of the present study should not be interpreted without taking into consideration certain strengths and limitations. The participation rate in the clinical examination was high (93%), while the respond rate to questionnaires was satisfactory (82%). Questionnaires completed by parents at home have limitations and the possibility of bias. However, they have been widely used in epidemiological studies. The main results of the study were derived through multivariate analysis, controlling for the confounding effect of gender, age, and nationality. The size of the sample was enough to reveal the effect of dietary factors on tooth wear. Yet, a larger sample could have helped to reveal correlations with more rare exposures, such as gastric acids, acidic medicine, and habits related to physical wear. The study comprised children attending public schools and kindergartens situated in an urban area; therefore, any extrapolation of the results must be done with caution. The quantitative estimators of tooth wear used are not standardized and validated yet. The number of teeth surfaces affected by tooth wear has been used as an estimator of tooth wear severity in previous studies [16, 17]. The Basic Erosive Wear Examination score is a recently proposed scoring system for the evaluation of the severity of tooth wear [6] that was adapted, following the suggestion of the authors [45], to the data of the present study. Due to the differences between the grading criteria of TWI and BEWE indices, it is possible that the cumulative score of sextants calculated in this study does not match the original BEWE score.

Conclusions

Tooth wear is a common condition in the deciduous dentition of urban children aged 5–7 years living in Greece, and the patterns of its distribution are similar to those reported for other countries. The progress of the lesions in the dentine was observed in half of the children.

The exposure to soft drinks and fresh fruit/juices significantly predicted the prevalence and the severity of tooth wear. However, the independent effect of the erosive process cannot always be isolated from the effect of the physiological wear due to the aging of dentition. The cumulative sextant score was more sensitive than the number of affected surfaces for the quantitative evaluation of tooth wear severity and for the risk assessment.

The reported consumption of sweetened beverages exceeded the dietary guidelines for the specific age group and further sets the risk for other health disorders, such as dental caries and obesity. Therefore, strategies to reduce the intake of soft drinks in children are expected to have multiple benefits preventing tooth wear in childhood and in later life, as well as many other general and oral health diseases.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Bartlett D, Drugmore C (2008) Pathological or physiological erosion—is there a relationship to age? Clin Oral Investig 12 (Suppl 1):S27–S31
2. Bardsley PF (2008) The evolution of tooth wear indices. Clin Oral Investig 12(Suppl 1):S15–S19
3. Eccles JD (1979) Dental erosion of non-industrial origin. A clinical survey and classification. J Prosthet Dent 42:649–653
4. Smith BG, Knight JK (1984) An index for measuring the wear of teeth. Br Dent J 156:435–438
5. Lussi A, Schaffner M, Hotz P, Suter P (1991) Dental erosion in a population of Swiss adults. Community Dent Oral Epidemiol 19 (5):286–290
6. Bartlett D, Ganss C, Lussi A (2008) Basic Erosive Wear Examination (BEWE): a new scoring system for scientific and clinical needs. Clin Oral Invest 12(Suppl 1):S65–S68
7. O'Sullivan EA (2000) A new index for the measurement of erosion in children. Eur J Paediatr Dent 1:69–74
8. Kreulen CM, Van't Spijker A, Rodriguez JM, Bronkhorst EM, Creugers NH, Bartlett DW (2010) Systematic review of the prevalence of tooth wear in children and adolescents. Caries Res 44(2):151–159
9. Mangueira DF, Sampaio FC, Oliveira AF (2009) Association between socioeconomic factors and dental erosion in Brazilian schoolchildren. J Public Health Dent 69(4):254–259
10. Kazoulis S, Seow WK, Holcombe T, Newman B, Ford D (2007) Common dental conditions associated with dental erosion in schoolchildren in Australia. Paediatr Dent 29(1):33–39
11. Rios D, Magalhaes AC, Honorio HM, Buzalaf MA, Lauris JR, Machado MA (2007) The prevalence of deciduous tooth wear in six-year-old children and its relationship with potential explanatory factors. Oral Health Prev Dent 5(3):167–171
12. Wiegand A, Muller J, Werner C, Attin T (2006) Prevalence of erosive tooth wear and associated risk factors in 2–7-year-old German kindergarten children. Oral Dis 12:117–124
13. Marinelli A, Alarashi M, Defraia E, Antonini A, Tollaro I (2005) Tooth wear in the mixed dentition: a comparative study between children born in the 1950s and the 1990s. Angle Orthod 75 (3):340–343
14. Luo Y, Zeng XJ, Du MQ, Bedi R (2005) The prevalence of dental erosion in preschool children in China. J Dent 33:115–121
15. Harding MA, Whelton H, O'Mullane DM, Cronin M (2003) Dental erosion in 5-year-old Irish school children and associated factors: a pilot study. Community Dent Health 20(3):165–170
16. Al-Majed I, Maguire A, Murray JJ (2002) Risk factors for dental erosion in 5–6 year old and 12–14 year old boys in Saudi Arabia. Community Dent Oral Epidemiol 30:38–46
17. Warren JJ, Yonezu T, Bishara SE (2002) Tooth wear patterns in the deciduous dentition. Am J Orthod Dentofacial Orthop 122:614–618
18. Ayers KM, Drummond BK, Thomson WM, Kieser JA (2002) Risk indicators for tooth wear in New Zealand school children. Int Dent J 52(1):41–46

19. Holbrook WP, Ganss C (2008) Is diagnosing exposed dentine a suitable tool for grading erosive loss? Clin Oral Invest 12(Suppl 1):S33–S39
20. Millward A, Shaw L, Smith AJ, Rippin JW, Harrington E (1994) The distribution and severity of tooth wear and the relationship between erosion and dietary constituents in a group of children. Int J Paediatr Dent 4:151–157
21. Maupome G, Ray JM (2000) Structured review of enamel erosion literature (1980–1999): a critical appraisal of experimental, clinical and review publication. Oral Dis 6(4):197–207
22. Hugoson A, Ekfeldt A, Koch G, Hallonsten A-L (1996) Incisal and occlusal tooth wear in children and adolescents in a Swedish population. Acta Odontol Scand 54:263–270
23. de Vis H, de Boever JA, van Gauwenberghe P (1984) Epidemiological survey of functional conditions of the masticatory system in Belgian children aged 3–6 years. Community Dent Oral Epidemiol 12:203–207
24. O'Brien M (1994) Children's dental health in the United Kingdom. OPCS Social Survey Division, HMSO, London
25. Bardsley PF, Taylor S, Milosevic A (2004) Epidemiological studies of tooth wear and dental erosion in 14-year-old children in North West England. Part 1: the relationship with water fluoridation and social deprivation. Br Dent J 197:413–416
26. Al-Dlaigan YH, Shaw L, Smith A (2001) Dental erosion in a group of British 14-year-old school children. Part I: prevalence and influence of differing socioeconomic backgrounds. Br Dent J 190:145–149
27. Bell EJ, Kaidonis J, Townsend GC (2002) Tooth wear in children with Down syndrome. Aust Dent J 47(1):30–35
28. Bernal M, Tsamtsouris A (1986) Signs and symptoms of temporomandibular joint dysfunction in 3 to 5 year old children. J Pedod 10(2):127–140
29. Suzuki T, Kikuchi M (2011) Diachronic changes of tooth wear in the deciduous dentition of the Japanese. In: Sasano T, Suzuki O (eds) Interface Oral Health Science 2009. session 1:148–149.doi: 10.1007/978-4-431-99644-6_28
30. Ganss C, Klimek J, Borkowski N (2002) Characteristics of tooth wear in relation to different nutritional patterns including contemporary and medieval subjects. Eur J Oral Sci 110:54–60
31. Hunter L, Patel S, Rees J (2009) The in vitro potential of a range of baby drinks. Int J Paediatr Dent 19(5):325–329
32. O'Sullivan EA, Curzon MEJ (2000) A comparison of acidic dietary factors in children with and without dental erosion. ASDC J Dent Child 67(3):186–92, 160
33. Murakami C, Oliveira LB, Sheiham A, Nahas Pires Correa MS, Haddad AE, Bonecker M (2011) Risk indicators for erosive tooth wear in Brazilian preschool children. Caries Res 45(2):121–129
34. Hasselkvist A, Johansson A, Johansson AK (2010) Dental erosion and soft drink consumption in Swedish children and adolescents and the development of a simplified erosion partial recording system. Swed Dent J 34(4):187–195
35. Nystrom M, Kononen M, Alaluusna S, Evalahti M, Vartiovaara J (1990) Development of horizontal tooth wear in maxillary anterior teeth from five to 18 years of age. J Dent Res 69:1,765–1,770
36. Harding MA, Whelton HP, Shirodaria SC, O'Mullane DM, Cronin MS (2010) Is tooth wear in the primary dentition predictive of tooth wear in the permanent dentition? Report from a longitudinal study. Community Dent Health 27:41–45
37. U.S. Department of Agriculture (2005) Dietary guidelines for Americans. Available at http://www.cnpp.usda.gov/Publications/DietaryGuidelines/2005/2005DGPolicyDocument.pdf. Accessed 24 Jan 2011
38. Supreme Scientific Health Council, Ministry of Health and Welfare (1999) Dietary guidelines for adults in Greece. Arch Hellen Med 16(5):516–524 (in Greek)
39. Lytle LA, Seifert S, Greenstein J, McGovern P (2000) How do children's eating patterns and food choices change over time? Results from a cohort study. Am J Health Promot 14:222–228
40. Chestnutt IG, Murdoch C, Robson KF (2003) Parents and carers' choice of drinks for infants and toddlers, in areas of social and economic disadvantage. Community Dent Health 20(3):139–145
41. Rodd HD, Patel V (2005) Content analysis of children's television advertising in relation to dental health. Br Dent J 199 (11):710–712
42. Chestnutt IG, Ashraf FJ (2002) Television advertising of foodstuffs potentially detrimental to oral health—a content analysis and comparison of children's and primetime broadcasts. Community Dent Health 19:86–89
43. Ludwig DS, Peterson KE, Gortmaker SL (2001) Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. Lancet 357:505–508
44. Shenkin JD, Heller KE, Warren JJ, Marshall TA (2003) Soft drink consumption and caries risk in children and adolescents. Gen Dent 51(1):30–36
45. Young A, Amaechi BT, Dugmore C, Holbrook P, Nunn J et al (2008) Current erosion indices—flawed or valid? Summary. Clin Oral Investig 12(Suppl 1):S59–S63