DENTAL EROSION IN CHILDREN: RISK FACTORS IN DAILY LIFE IN THE 21ST CENTURY

Dien L. Gambon

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De vrouw zou zelfstandig en onafhankelijk moeten kunnen zijn en gelijke kansen moeten krijgen tegen gelijke beloning als de man.

Mr. Maria Johanna Gambon-Burnier (1886) promoveerde op 16 oktober 1911.
Zij was de oma van Dien Gambon.

Voor: Peter-Hans, Pieter en Martijn
Jeanne, Alice en Nely

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Chapter 1

Introduction

INTRODUCTION

The term 'erosion', derived from the Latin verb *erodere* (to gnaw, to corrode), describes the process of gradual destruction of the surface of material, usually by mechanical, electrolytic or chemical processes. The clinical term dental erosion or *erosio dentium* is defined as the result of a pathologic, chronic, localized, painless loss of dental hard tissue chemically etched away from the tooth surface by acid and/or chelation without the involvement of microorganisms (ten Cate and Imfeld, 1996).

Dental erosion rarely occurs alone (Meurman and ten Cate, 1996; Addy and Shellis, 2006) but interacts with other types of mechanical wear such as abrasion, (Davis and Winter, 1980; Attin *et al.*, 1999; Jaeggi and Lussi, 1999), attrition (Kaidonis *et al.*, 1998) and demastication (Ganss *et al.*, 1999). Abrasion is tooth wear caused by interaction between teeth and another material, attrition is tooth wear caused by tooth-tooth contact and demastication is wear caused by the mechanical interaction between teeth and food. Gradual loss of dental hard tissues is often indicated with the general term 'tooth wear'.

ETIOLOGY OF DENTAL EROSION

The acids that cause dental erosion may come from intrinsic (e.g., gastroesophageal reflux, vomiting) or extrinsic sources (e.g., acidic beverages, citrus fruits) (Imfeld, 1996). Causes of erosion due to intrinsic acids include vomiting, regurgitation, gastroesophageal reflux or rumination (Scheutzel, 1996; Bartlett, 2006). Causes of tooth erosion due to extrinsic acids are frequent consumption of acidic beverages, some medicaments and daily exposure to acids. Examples of the latter are factory workers exposed to acidic fumes or aerosols, professional wine tasters and competitive swimmers (ten Bruggen Cate, 1968; Centerwall *et al.*, 1986; Tuominen and Tuominen, 1991; McIntyre, 1992; Wiktorsson *et al.*, 1997).

As lifestyle has changed over the last decades, both the total amount and the frequency of the consumption of acidic food and beverages have increased (Calvadini *et al.*, 2000; O'Sullivan and Curzon, 2000; Lussi and Schaffner, 2000; British Soft Drinks Association, 1991). Moderate consumption of acidic food and beverages does not necessarily lead to erosive tooth wear. Frequency and duration of intake are probably more important factors than total intake of acidic drinks. Furthermore, peculiar eating, drinking and swallowing habits may increase the contact time of the acidic drink with the tooth surface and therefore further aggravate its erosive effects (Mackie and Hobson, 1986; Harrison and Roder, 1991; Millward *et al.*, 1994b; Edwards *et al.*, 1998; Johansson *et al.*, 2004). People with a more healthy lifestyle usually consume more fruits and vegetables and tend to have a better oral hygiene, which makes them more susceptible to dental erosion (Ganss *et al.*, 1999). Oral hygiene products and medication with low pH have also been suggested as potential causes of erosion (Zero, 1996).

PREVALENCE OF DENTAL EROSION

There are indications that the prevalence of erosive lesions is increasing, especially in younger age groups (Deery *et al.*, 2000; Linett and Seow, 2001; Nunn *et al*., 2003; Dugmore and Rock, 2004; Jaeggi and Lussi, 2006; Kazoullis *et al*., 2007). However, these data were collected in different countries. It is difficult to compare prevalence studies in various countries due to differences in diagnostic criteria, indices, socioeconomic conditions, cultural factors and different teeth assessed.

In preschool children between the ages of 2-5 years dental erosion was found to vary from 6 to 50% in deciduous teeth (Al-Malik *et al.*, 2002; Luo *et al*., 2005; Harding *et al*., 2003; Millward *et al*., 1994a and b). In young children in the age group of 5-12 years, 100% of the children had some signs of enamel erosion, 48% had dentinal erosion and 14% had already lesions in the permanent dentition (Jaeggi and Lussi, 2004).

Looking at adolescents (aged between 9-17 years) 11-100% showed evidence of erosion. In 1999, only 3% of Dutch children of 12 years had dental erosion. In a follow-up study in 2002, however, tooth wear was observed in no less than 23% of the 12-year-old children (Truin *et al.*, 2005). In 2005 the percentage of 12-year-olds with dental erosion remained unchanged compared with 2002: 24% (Truin *et al.*, 2007). Another Dutch study showed that dental erosion was present in 32% of 622 children (mean age 11.9 years), and increased to 43% during the next 1.5 years (El Aidi *et al*., 2008). In another study it was found that the number of new tooth surfaces exhibiting erosion, in erosion-free children, decreased significantly with age, while the progression in children with erosion did not change (El Aidi *et al*., 2010).

Three other longitudinal studies assessed the increase in number of subjects with dental erosion. The incidence had increased to 27% over 1.5 years (Nunn *et al*., 2001) and to 12% over two years in the United Kingdom (Dugmore and Rock, 2003) and 18% over five years in Germany (Ganss *et al*., 2001).

Prevalence data indicate that boys in general have more erosive lesions than girls (Milosevic *et al*., 1994; Al-Dlaigan *et al*., 2001; van Rijkom *et al*., 2002; Dugmore and Rock, 2003; Bardsley *et al*., 2004; Truin *et al*., 2005).

PATHOGENESIS OF DENTAL EROSION

Chemical Factors

When enamel comes into contact with acid and/or chelators dental erosion starts with the loss of mineral. This is characterized by the softening of the dental surface and the increase of porosity (Meurman and ten Cate, 1996; Jaeggi and Lussi, 1999) followed by permanent loss of the demineralized tooth structure (Attin *et al*., 1997; Eisenburger *et al*., 2000). At the same time the softened surface layer becomes vulnerable to subsequent mechanical wear (Featherstone and Lussi, 2006).

Dental enamel is composed primarily of hydroxyapatite. Hydroxyapatite is a highly insoluble mineral at neutral pH. However, when the pH of the oral fluid is below the critical pH of enamel, hydroxyapatite gets into solution. The critical pH is inversely proportional to the concentrations of calcium and phosphate in the oral fluid. In people with low salivary concentrations of calcium and phosphate, the critical pH may be 6.5, whereas in individuals with high salivary calcium and phosphate concentrations, it may be 5.5. The fluid phase of dental plaque contains much higher concentrations of calcium and phosphate than does saliva, and therefore the critical pH in the plaque fluid may be as low as 5.1 (Dawes, 2003). Therefore, the pH of dietary substances alone is not predictive of its potential to cause erosion. Other parameters modify the erosive potential such as the buffering capacity of the acidic drink, the chelating properties, the presence of calcium and/or fluoride, the adhesion of the product to the dental surface (Ireland *et al*., 1995) and the salivary flow rate (Hara *et al*., 2006). The greater the buffer capacity of foods and drinks, the longer it will take for the saliva to neutralize the acid. Therefore, solutions with a low pH may cause dental erosion particularly if the acidic attack is of long duration, and repeated over time (Meurman and ten Cate, 1996).

The calcium-chelating properties of an acid, e.g. citric acid, will further enhance the erosive potential. On the other hand, a high concentration of calcium, phosphate and fluoride in food and beverages may have a protective effect (Lussi *et al*., 1993; Larsen, 1973; Attin *et al*., 2003). Although yogurt has a pH as low as 4.0 it hardly has any erosive effect due to its high calcium and phosphate content (Lussi and Jaeggi, 2006).

DENTITION RELATED FACTORS

Deciduous and permanent teeth show anatomical differences. Deciduous teeth are smaller and differ in morphology, structure and composition of the enamel. The enamel is less thick. Because of the thin enamel in deciduous teeth it is conceivable that erosive attacks will easier progress into the dentine, resulting in more advanced lesions after a short exposure to acid (Hunter *et al*., 2000a). The increased susceptibility of deciduous enamel to erosion especially becomes manifest when the frequency of acid consumption is increased (Hunter *et al*., 2000a and b; Johansson *et al*., 2001; Davies *et al*., 2008). Furthermore as the enamel of deciduous teeth is softer, the teeth are more vulnerable to mechanical wear than permanent teeth (Attin *et al.*, 1997).

BIOLOGICAL FACTORS

Some biological factors protect against the development of dental erosion (Hara *et al*., 2006). Saliva is considered to be the most important biological factor due to its ability of diluting and neutralizing the acids in the oral fluid, depending on the flow rate and buffering capacity. Saliva also protects against demineralisation and will enhance remineralisation due to the presence of calcium and phosphate (Meurman and ten Cate, 1996). Salivary mucins and other salivary proteins are constituents of the acquired pellicle. This protein film protects the underlying enamel against both mechanical wear and erosion by retarding the diffusion of H^+ ions to the tooth surface (Nieuw Amerongen *et al*., 1987; Hannig and Balz, 1999). Other biological factors that play a role are, for example, dental anatomy, occlusion and genetic factors such as the type of dental substrate (permanent and primary enamel, dentine) and fluoride exposure. In addition erosive tooth wear is influenced by contact of the tongue and soft tissues with the dental surface (Holst and Lange, 1939; Gregg *et al*., 2004).

CASE REPORT

A 9-year-old boy having caries was referred to a paediatric dental clinic after two previous extractions in a general practice. He was a healthy child without any medication, functioning psychologically and emotionally well. He liked to play soccer and was fond of playing computer games.

Intraoral examination revealed a mixed dentition with severe tooth wear and caries in the primary molars. A deep bite, enamel cupping and attrition signs and a flattened surface were observed (Figures 1 and 2). The first primary molar on the right side of the mandible (84)

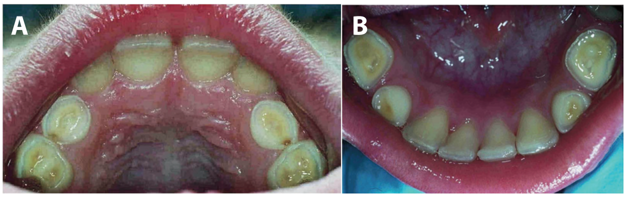

Figure 1. Dental cupping and caries in the upper (A) and lower jaw (B).

Figure 2. Deep bite right (A), front (B) and left (C).

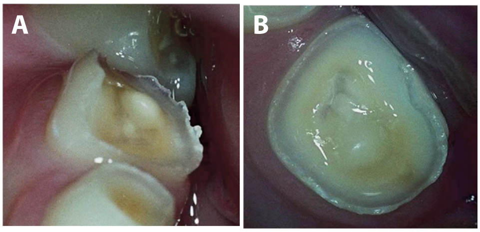

Figure 3. Occlusal wear of the 84 during the initial presentation (A) and during the subsequent visit one week later (B).

showed an occlusal surface with a thin, sharp edge of enamel (Figure 3A). The radiographs did not show pulp exposure.

Only one week later, the surface of the 84 was already flatter (Figure 3B). During the dental sessions, the molars were restored with a resin-based material (Dyract© compomer, De Trey, Konstanz, Germany) (Johansson *et al*., 2008). At the same time, the boy and his mother were asked to record his consumption pattern in a 6-day food diary. Although his diet was not particularly erosive, still the newly placed fillings came loose within several weeks, and the tooth wear continued.

When questioned in detail, the boy told that he consumed only one glass of soft drink per day over a period of one to two hours while he was gaming on his computer intensively. Incidentally, he was holding the soft drink over his teeth for a moment.

After personal advice, the boy changed his consumption pattern. This stopped the progression of caries, but the tooth wear progressed over the next two years (Figure 4). This suggests that factor(s) other than diet might have contributed to the problem, e.g. eating/drinking habits, reduced salivary flow rate or bruxism during night time. A systemic disease, or its medical treatment, can probably be excluded as cause of the progression in tooth wear, because the boy appeared healthy and did not use any kind of medication (Gambon *et al*., 2010).

Figure 4. Primary molars 64, 75 and premolars 25, 34 (two years after initial presentation).

AIM OF THE STUDY

There are many factors which are involved in and interact with the process of dental erosion such as habits, knowledge, education and socioeconomic status (Figure 5).

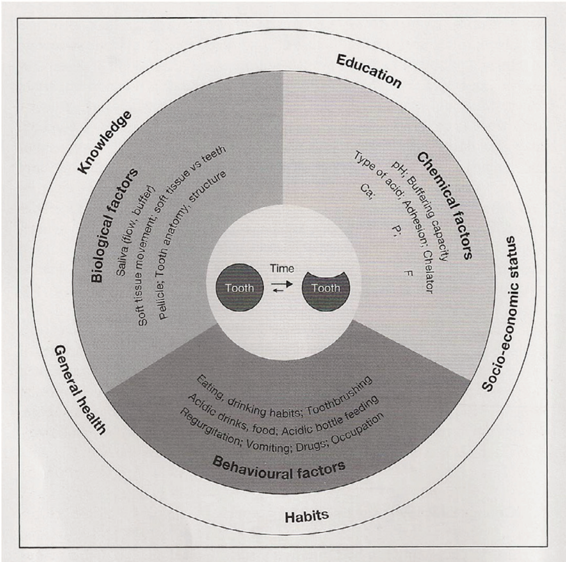

Figure 5. Interactions of different factors in the development of erosive tooth wear (Lussi, 2006).

Depending on the interactions of the biological, behavioural and chemical factors some individuals will exhibit more erosive tooth wear than others.

The aim of the present thesis is to analyse potential risk factors in developing erosive tissue loss to which children and adolescents are exposed in the 21st century. Specific aims of the present study are:

1. To investigate which potentially erosive foods and beverages are available at schools (Chapter 2).
2. To determine the amounts of acidic drinks consumed by children visiting a secondary school (Chapter 3).
3. To determine the erosive potential of different types of acidic candies (Chapter 4 - 7).
4. To analyse the use of drinking straws by young children and the potential relation to tooth wear (Chapter 8).
5. To develop recommendations to prevent dental erosion in young children and adolescents (Chapter 9).

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Chapter 2

Erosive beverages in secondary school canteens in the Netherlands

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Submitted for publication

ABSTRACT

Objective: The aim of this study was to collect information on the erosive foods and beverages available at canteens of secondary schools in the Netherlands.
Research design: A cross-sectional study was performed among 43 locations of 37 schools in the Netherlands. All different types of food and drinks for sale at the school canteen were registered. Drinks were classified as non-erosive or potentially erosive. Potential relations between the number of (erosive) products and level of education, number of students, business hours and number of vending machines were explored with ANOVA and Spearman's rank order correlation analysis.
Results: Many different products are available in canteens of Dutch secondary schools, a high proportion of the drinks being potentially erosive (71.8±12.9%). The number of different products available, the number of different beverages available and the number of erosive drinks were all related to the number of students per school, but not to the type of education. The number of drinks available and number of erosive drinks correlated with the opening hours of the canteens and the number of vending machines.
Conclusion: In the Netherlands, school canteens offer a wide range of products, including many potentially erosive beverages. Consumption of these products during school hours may contribute to the development of dental erosion in children.

INTRODUCTION

The prevalence of overweight, obesity and diabetes in children is rapidly increasing in many countries. A major contributing factor is the increased consumption of food, drinks and snacks (Pearson *et al*., 2010; Zellner *et al*., 2007). There is also increasing concern about the high and increasing prevalence of dental erosion in children (Jaeggi and Lussi, 2006).

Dental erosion is the pathologic, chronic, localized loss of dental hard tissue due to chemical dissolution of the tooth surface by acid and/or chelating agents without bacterial involvement (ten Cate and Imfeld, 1996). The etiology of dental erosion is considered to be multifactorial. However, several studies have shown a relation between the presence of dental erosion and a high consumption of cola-type and other acid containing soft drinks. During the last decades of the twentieth century, the consumption of soft drinks has increased considerably (Calvadini *et al*., 2000; Gleason and Suitor, 2001). Soft drinks contain acids such as phosphoric or citric acids, and their pH is often less than 4.0, far below the critical pH for dissolution of dental enamel (Tahmassebi *et al*., 2006; Larsen and Nyvad, 1999).

School canteens provide children with a wide range of food choices. In the Netherlands, school canteens hardly offer hot meals during lunchtime. Instead, they usually sell a variety of snacks and beverages.

To our knowledge, no previous studies have investigated the availability of potentially erosive foods and beverages in school canteens. Therefore, we have performed an inventory of the different types of foods and (potentially erosive) drinks available in school canteens and explored the potential relation with type of education, number of students, opening hours and number of vending machines.

EXPERIMENTAL METHODS

Forty-three locations of 37 different schools canteens in 9 different cities in the Netherlands were visited in 2008 or 2009. All different food products and drinks available in the canteen were registered. The drinks were classified as non-erosive or potentially erosive according to previously published guidelines (Lussi and Jaeggi, 2006). At each school, staff members provided information about the educational level, the number of students, the opening hours of the canteen and the number of vending machines. Approval for the study was obtained from the board of each participating school.

Statistical analysis was performed using the statistical software package SPSS version 15.0.1 (SPSS Inc., Chicago, IL, USA). Differences in number of consumptions and opening hours were analysed with ANOVA. Possible relations between variables were explored using Spearman's rank order correlation coefficients. All levels of significance were set at $p < 0.05$.

RESULTS

The secondary schools that were visited differed in level of education (Table 1). The majority of the secondary schools were comprehensive schools offering more than one educational level (63%). Fifty-eight percent of the schools were situated in major cities (population > 250,000). The number of students varied from 65 to 1750 (average 703±447). The opening hours of the canteen varied from 0 (one school had no canteen) to 570 minutes (average 155±145) and the number of vending machines from 1 to 15 (average 4.2±2.8).

Table 1. Levels of education at the schools visited.

Preparatory vocational education	21%
Preparatory vocational education and Higher general secondary education	2%
Higher general secondary education and Pre-university education	30%
Pre-university education	16%
Preparatory vocational education, Higher general secondary education and Pre-university education	30%

The number of different products available in the canteen varied from 14 to 142 (average 69±26) including 4 to 35 different drinks (average 20±7). Of the available drinks 71.8%±12.9 was classified as potentially erosive.

The number of different products, the number of drinks and the number of potentially erosive drinks correlated significantly (Table 2). Each of these three variables correlated significantly with the number of students, the opening hours of the canteen and number of vending machines.

There was no correlation between educational level and location of the school (in a major city or not), or the number of food products, the number of drinks and the number of potentially erosive drinks of the canteen (data not shown).

Table 2. Non-parametric correlations between the number of food products, the number of drinks and the number of potentially erosive drinks available at school canteens and the number of students, opening hours of the canteens and number of vending machines (Spearman's rank order correlation coefficients).

	Number of products	Number of drinks	Number of erosive drinks
Number of products	----	r = 0.849 p < 0.0005	r = 0.823 p < 0.0005
Number of students	r = 0.384 p = 0.011	r = 0.415 p = 0.006	r = 0.369 p = 0.015
Opening hours of canteen	r = 0.389 p = 0.010	r = 0.395 p = 0.009	r = 0.409 p = 0.006
Number of vending machines	r = 0.377 p = 0.013	r = 0.391 p = 0.010	r = 0.351 p = 0.021
Number of erosive drinks	r = 0.823 p < 0.0005	r = 0.927 p < 0.0005	----

DISCUSSION

Schools are in a unique position to improve the health status and dietary behaviour of children. Therefore, the current range of food products and beverages available in Dutch school canteens should be of concern. The products available in the canteens include a high percentage of soft drinks and potentially erosive beverages. The products are widely available through vending machines and relatively long opening hours of the canteen (on average two-and-a-half hours per day).

Overconsumption of soft drinks is implicated as a contributing factor in the development of obesity (Ludwig *et al*., 2001; James and Kerr, 2005) and diabetes (Botero and Wolfsdorf, 2005). To reduce this risk, Australian state schools have banned the sale of sugar-containing beverages, which had to be replaced by sugar free alternatives and non-artificially-sweetened fruit juices (Victorian State Government, 2007). This could have a potential positive effect on the development of obesity and caries. However, it is not clear whether this will affect the development of dental erosion, as conflicting results have been reported on the erosive potential of sugar-containing soft drinks versus their sugar free variants. According to Lussi and Jaeggi (2006) the erosive potential of sugar free soft drinks does not differ significantly from their sugar-containing counterparts. However, two other studies suggest that diet cola beverages were less erosive than sugar-containing cola drinks (Owens *et al.,* 2007; Rytömaa *et al*., 1988).

It seems difficult to diminish soft drink consumption by school children. Placing free water coolers in Dutch secondary schools had no significant effect on the sale of sugar-sweetened beverages in school canteens (Visscher *et al*., 2010). Less erosive drinks have been developed containing increased levels of calcium, phosphate and/or fluoride (Larsen and Nyvad, 1999; Hughes *et al*., 1999). However, the altered taste limits widespread acceptance by consumers.

A limitation of the present study is that only the food products and drinks available in the school canteen were registered and not the actual sales of each product. Therefore, it is possible that healthy and non-erosive items have much higher sale figures than the less healthy and potentially erosive items. On the other hand, it seems unlikely that food products and beverages that are hardly sold will remain available in school canteens.

Despite this limitation, we conclude that Dutch school canteens offer a wide range of food products and drinks, including potentially erosive beverages. Consumption of these widely available products at school may contribute to the development of dental erosion in children. Restrictions on the canteen assortment, a reduction in opening hours of the canteen and a ban on school vending machines could help to limit the exposure of Dutch school children to potentially erosive drinks.

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Chapter 3

Patterns in consumption of potentially erosive beverages among adolescent school children in the Netherlands

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ABSTRACT

Aim: To determine the frequency of intake and patterns in consumption of potentially erosive beverages in school children in the Netherlands.
Methods: A cross-sectional single centre study was performed among 502 school children in Rotterdam, the Netherlands, in age varying between 12 and 19 years old. Data on consumption of soft drinks, energy drinks, sports drinks and alcopops were obtained through a self-reported questionnaire. Gender- and age-related differences in consumption were analysed with Chi-square, Kruskal-Wallis and Mann-Whitney tests. Associations between variables were investigated with Chi-square tests and Spearman's rank order correlation analysis.
Results: Boys consumed soft drinks, energy drinks and sports drinks more frequently than girls, and on average also consumed higher amounts of these drinks. No gender-related differences were observed in alcopop consumption. Consumption of all drinks was most frequent at 14 or 15 years of age, with the exception of alcopops which was most frequently consumed by 16-year-old school children. Significant positive associations were observed between the consumption of soft drinks, energy drinks and/or sports drinks. Alcopop consumption was only associated with consumption of energy drinks.
Conclusions: Consumption of soft drinks, energy drinks, sports drinks and alcopops by school children is related to age and gender. The significant positive associations between the consumption of these drinks suggest that a subgroup of school children exists with a high cumulative intake of these potentially erosive drinks.

INTRODUCTION

Dental erosion is the loss of dental hard tissue that is chemically etched away from the tooth surface by acid without bacterial involvement (ten Cate and Imfeld, 1996). In Europe, the prevalence of dental erosion is high among children and adolescents, and the incidence seems to be increasing (Al-Dlaigan *et al.*, 2001; Bartlett *et al.*, 1998; Dugmore and Rock, 2004; Nunn *et al.*, 2003).

Consumption of acidic beverages is considered an important factor involved in the etiology of dental erosion. Cola-type and other soft drinks contain high levels of phosphoric, citric or other acids, resulting in pH values below 4.0 (Lussi *et al*., 2004). Similar pH values are frequently observed in sports drinks and energy drinks, due to high levels of citric acid (Coombes, 2005; Hooper *et al*., 2005).

During the last two decades, *in vitro* experiments have clearly proved the erosive potential of soft drinks, sports drinks and energy drinks (Ehlen *et al.*, 2008; Von Fraunhofer and Rogers, 2004; Meurman *et al.*, 1990; Milosevic, 1997; Owens and Kitchens, 2007; Rees *et al.*, 2005). Although increasing the length or frequency of exposure to acidic drinks resulted in increased erosion *in vitro*, the effect was not proportional (Van Eygen *et al.*, 2005; Hunter *et* al., 2000; Maupomé *et al*.,1998; West *et al*., 2000).

Several observational studies support an association between soft drink consumption and the incidence or severity of dental erosion (Al-Dlaigan *et al*., 2001; Al-Majed *et al*., 2002; Al-Malik *et al*., 2001; Dugmore and Rock, 2004; Järvinen *et al*., 1991; Jensdottir *et al*., *2004*; Johansson *et al*., 2002; Millward *et al*., 1994). However, many other studies failed to find a significant relationship (Bartlett *et al.*, 1998; Nunn *et al.*, 2003; Mathew *et al*., 2002; Milosevic *et al*., 1997; van Rijkom *et al.*, 2002; Sirimaharaj *et al*., 2002; Waterhouse *et al*., 2008). Cross-sectional observational studies and a case control study also failed to show a relationship between consumption of sports drinks and dental erosion (Mathew *et al*., 2002; Sirimaharaj *et al*., 2002; Milosevic *et al*., 1997; O'Sullivan and Curzon, 2000). In a case control study, however, a significant increased risk of erosion was found when sports drinks were consumed weekly (Järvinen *et al*., 1991). Studies investigating the relationship between the consumption of energy drinks and dental erosion are scarce in the scientific literature.

The observation that many studies fail to demonstrate a relationship between dental erosion and consumption of acidic beverages, indicate that focussing on a single type of drink may be too simplistic (Coombes, 2005). Therefore, the aim of the present study was to investigate whether a relationship exists in the amount of these acidic beverages consumed by adolescent school children per week. In addition, age- and gender related differences in consumption of these potentially erosive beverages were investigated.

MATERIALS AND METHODS

A cross-sectional single centre study was conducted at a public high school in Rotterdam. All children of the school were invited to participate, with the exception of the graduating classes. This resulted in a study group of 502 children (12-19-years- old) with a multicultural background. This study was performed according to the guidelines of the Medical Ethical Committee of the Vrije Universiteit (Amsterdam, the Netherlands) and approval for the study was obtained from the board of the school.

A questionnaire was developed to determine the consumption of different types of beverages, which focused on the consumption of soft drinks, sports drinks, energy drinks and alcopops. To clarify these types of drinks to the participants, three examples of each type of drink were mentioned. The consumption of the beverages was recorded as the number of drinks consumed during the last week. Additional questions were included which asked about the brand(s) used, age and gender. The questionnaire was administered anonymously at school, but the children were supervised whilst completing it to ensure that they did not discuss the questions with each other. Due to the fact that some children did not disclose their age or gender, the total number of respondents may differ between analyses.

The statistical analysis was performed using the statistical software package SPSS version 15.0.1 (SPSS Inc., Chicago, IL, USA). Age and gender-related differences in consumption pattern and number of cans consumed were investigated with Chi-square tests, Kruskal-Wallis tests and Mann-Whitney tests. The association between consumption of different types of drinks was explored with Chi-square tests and Spearman's correlation coefficients. All levels of significance were set at $p < 0.05$.

RESULTS

The data in Table 1 show that the majority of the school children in the study group consumed soft drinks during the last week (85.2%). Sports drinks and energy drinks were less frequently used (44.7% and 39.4%, respectively) and only a minority of the school children reported the consumption of alcopops (12.8%). For the total study group, the mean number of drinks consumed showed a similar trend with 4.8 units of soft drinks, 1.7 units of energy drinks, 1.1 units of sports drinks and 0.4 units of alcopops.

Boys and girls were equally represented in the study group (49.5% and 50.5%, respectively). When stratified according to gender, boys reported more frequently the use of soft drinks, energy drinks and sports drinks than girls (Table 2). On average, boys also consumed significantly higher amounts of each of these drinks. When the analyses were limited to the school children that reported use of a specific drink ('users'), the amount consumed by boys remained significantly higher for both soft drinks and sports drinks (Table 2).

Table 1. Percentage of school children reporting consumption of soft drinks, energy drinks, sports drinks and alcopops last week, number of drinks consumed by the total study group and number of drinks consumed by those children reporting use last week.

	Use last week (%)	Number of drinks (mean ± S.D.)	
		Total	Users
Soft drinks	85.2% (n=500)	4.8 ± 6.3 (n=491)	5.6 ± 6.5 (n=417)
Energy drinks	39.4% (n=500)	1.7 ± 3.7 (n=499)	4.1 ± 4.8 (n=196)
Sports drinks	44.7% (n=499)	1.1 ± 2.0 (n=495)	2.4 ± 2.0 (n=218)
Alcopops	12.8% (n=501)	0.4 ± 1.7 (n=500)	3.3 ± 3.8 (n= 63)

Table 2. Percentage of school children reporting consumption of soft drinks, energy drinks, sports drinks and alcopops last week, number of drinks consumed by the total study group and number of drinks consumed by those children reporting use last week, all stratified according to gender.

	Use last week (%)		Number of drinks (mean ± S.D.)			
			Total		Users	
	Male	Female	Male	Female	Male	Female
Soft drinks	91.5% (n=185)	80.2% [b] (n=189)	6.1±7.6 (n=185)	3.5±4.7 [f] (n=189)	6.7±7.7 (n=169)	4.3±4.9 [f] (n=151)
Energy drinks	45.7% (n=188)	32.3% [a] (n=191)	2.0±3.7 (n=188)	1.0±2.3 [e] (n=191)	4.3±4.5 (n=86)	3.2±3.2 (n=61)
Sports drinks	51.8% (n=186)	33.3% [c] (n=191)	1.4±2.2 (n=186)	0.8±2.0 [f] (n=191)	2.6±2.4 (n=100)	2.3±2.9 [d] (n=63)
Alcopops	10.1% (n=188)	10.9% (n=192)	0.4±1.8 (n=188)	0.3±1.3 (n=192)	3.7±4.4 (n=19)	2.7±3.0 (n=21)

Chi-square versus male: [a] $p < 0.01$; [b] $p < 0.005$; [c] $p < 0.0005$
Mann-Whitney versus male: [d] $p < 0.05$; [e] $p < 0.005$; [f] $p < 0.0005$

Table 3 and 4 show the age-related differences in the consumption of the investigated drinks. Consumption of soft drinks, energy drinks and sports drinks was most frequent and the mean consumption was the highest at 14 or 15 years of age, after which it declined. Alcopop consumption was most frequent and highest in 16- year-old school children. The age-related differences in the consumed number of soft drinks remained significant when the analyses were limited to 'users'. For sports drinks and alcopops, the number of consumptions by 'users' did not show age-related differences (Table 4).

Significant associations were observed between the consumption of soft drinks, energy drinks and sports drinks (Table 5). Alcopop consumption was associated with consumption of energy drinks but not with the consumption of soft drinks or sports drinks. Significant correlations were also observed between the number of soft drinks, energy drinks and sports drinks consumed in the preceding last week (Table 6). The number of alcopops consumed showed a significant relation only with the consumption of energy drinks.

Table 3. Percentage of school children reporting consumption of soft drinks, energy drinks, sports drinks and alcopops last week, stratified according to age.

Years	≤ 13 (n=102)	14 (n=86)	15 (n=93-95)	16 (n=89-90)	≥17 (n=72-76)
Soft drinks [a]	80.4%	91.9% [c]	88.4%	87.8%	77.3% [e]
Energy drinks	34.3%	44.2%	41.5%	38.9%	36.8%
Sports drinks [b]	44.1%	53.5%	53.2%	47.2%	27.6% [cfgh]
Alcopops [a]	4.9%	9.3%	13.7% [c]	20.0% [de]	10.5%

Chi-square for age-related differences: [a] $p < 0.05$; [b] $p < 0.01$.
Chi-square versus 13-yr: [c] $p < 0.05$, [d] $p < 0.005$; versus 14-yr: [e] $p < 0.05$, [f] $p < 0.005$; versus 15-yr: [g] $p < 0.005$; versus 16-yr: [h] $p < 0.05$.

Table 4. Number of soft drinks, energy drinks, sports drinks and alcopops consumed by the total study group and number of drinks consumed by those children reporting use last week, stratified according to age.

Years		≤ 13	14	15	16	≥17
Soft drinks						
	Total [c]	3.3±5.0 (n=102)	5.5±6.1 [f] (n=86)	6.1±6.9 [f] (n=94)	4.5±4.6 [e] (n=89)	5.1±9.3 [i] (n=72)
	Users [c]	4.1±5.3 (n=82)	6.0±6.2 [e] (n=76)	6.9±7.0 [f] (n=94)	5.1±4.5 [d] (n=90)	6.6±10.1 [d] (n=55)
Energy drinks						
	Total	1.2±2.5 (n=102)	1.5±2.6 (n=86)	1.4±2.7 (n=94)	1.8±4.0 (n=90)	1.8±4.9 (n=75)
	Users	3.4±3.3 (n=35)	3.5±3.4 (n=38)	3.5±3.3 (n=39)	4.7±5.2 (n=35)	4.9±7.3 (n=27)
Sports drinks						
	Total [b]	1.1±2.7 (n=102)	1.4±2.1 (n=86)	1.2±1.7 (n=93)	1.0±1.5 (n=89)	0.7±2.0 [dhjk] (n=74)
	Users	2.6±3.6 (n=45)	2.6±2.2 (n=46)	2.2±1.8 (n=48)	2.1±1.5 (n=42)	2.6±3.4 (n=19)
Alcopops						
	Total [a]	0.4±2.3 (n=102)	0.2±0.6 (n=86)	0.4±1.4 [d] (n=95)	0.5±1.4 [eg] (n=90)	0.4±1.2 (n=76)
	Users	7.2±8.7 (n=5)	1.9±1.1 (n=8)	3.0±2.4 (n=13)	2.4±2.4 (n=18)	3.4±1.8 (n=8)

Kruskal-Wallis for age-related differences: [a] $p < 0.05$; [b] $p < 0.001$; [c] $p < 0.0005$.
Chi-square for differences versus 13-yr: [d] $p < 0.05$, [e] $p < 0.005$, [f] $p < 0.0005$; versus 14-yr: [g] $p < 0.05$, [h] $p < 0.0005$; versus 15-yr: [i] $p < 0.05$, [j] $p < 0.0005$; versus 16-yr: [k] $p < 0.005$.

DISCUSSION

The results from this study indicate that adolescent school children in the Netherlands have a high level of intake of acidic drinks, particularly soft drinks. Eighty-five percent of the children consumed soft drinks, which is in agreement with other recent surveys among teenagers in

Table 5. Associations between consumption of soft drinks, energy drinks, sports drinks and alcopops last week (Chi-square tests).

	Energy drinks	Sports drinks	Alcopops
Soft drinks	p<0.0005 (n=499)	p=0.011 (n=498)	p=0.191 (n=500)
Energy drinks		p<0.0005 (n=498)	p<0.0005 (n=500)
Sports drinks			p=0.113 (n=499)

Table 6. Non-parametric correlations between number of soft drinks, energy drinks, sports drinks and alcopops consumed last week (Spearman's rank order correlation coefficients).

	Energy drinks	Sports drinks	Alcopops
Soft drinks	0.344 p<0.0005 (n=489)	0.248 p<0.0005 (n=489)	0.076 p=0.095 (n=491)
Energy drinks		0.189 p<0.0005 (n=493)	0.155 p=0.001 (n=498)
Sports drinks			0.080 p=0.076 (n=494)

Europe and the USA (Al-Dlaigan *et al*., 2001; Dugmore and Rock, 2004; Harnack *et al*., 1999). The proportion of school children consuming soft drinks was the highest in the 14-years age group (Table 3). Dugmore and Rock (2004) also reported an increase between the age of 12 and 14 (from 77% to 92%). Compared with soft drinks, the percentages of adolescents reporting consumption of sports drinks and energy drinks are much lower, and similar to previous reports (Table 1) (Al-Dlaigan *et al*., 2001; Grimm *et al*., 2004).

Only a minority of school children reported the use of alcopops (Table 1). These alcoholic beverages are known to cause erosion (Hughes and Rees, 2008). Dutch law prohibits the sale of alcoholic beverages to individuals under the age of 16. This probably explains the increase in consumption of alcopops in the 16-years age group (Table 3). Although the proportion of underage drinkers is relatively low, the number of alcopops consumed by underage users is not statistically significant from children of 16 or older (Table 4).

Boys consume more frequently and on average higher amounts of soft drinks, energy drinks and sports drinks than girls (Table 2) (Al-Dlaigan *et al*., 2001; Jensdottir *et al*., *2004*). This higher intake of acidic drinks could explain the significantly higher prevalence of dental erosion in boys than in girls in the Netherlands (van Rijkom *et al*., 2002; El Aidi *et al*., 2008).

Several studies indicate that a minority exists within each population with a disproportionally high intake of soft drinks. Such subgroups have been identified among (pre)school children in Britain, Norway, Brazil and Kuwait (see Maupomé *et al*., 1998). The significant positive associations between consumption of soft drinks, energy drinks and sports drinks in our study (Table

5 and 6) indicate that these subgroups of school children not only have a high intake of soft drinks, but consume other types of acidic beverages more frequently as well. Consequently, their teeth are subjected very frequently to attacks by acid.

The present cross-sectional study has some limitations. In the first place, it was a single centre study performed at a high school which may not be representative of the national population. It is also important to consider the reliability of self-reporting dietary habits with the possibility of under- or over-reporting. Furthermore, due to the cross-sectional nature of the study, seasonal changes in consumption pattern may have affected the results (Ganss, 2008).

The erosive potential of acidic beverages *in vivo* will also depend on the way of drinking. E.g. it has been suggested that drinking through a straw may reduce the risk of developing erosion (Edwards *et al*., 1998). The method of drinking was not explored in the present study, neither did we distinguish between the consumption of regular and diet drinks. *In vitro*, diet cola beverages should be less erosive than the sugar-containing versions (Owens *et al*., 2007; Rytömaa *et al*., 1988), although the erosive potential of sugar free soft drinks does not differ significantly from the regular counterparts (Lussi and Jaeggi, 2006). So consumption of sugar-containing versions might have a higher risk of dental erosion, but also increase the risk of developing caries and obesity. Taken together, these limitations indicate the need for longitudinal studies on the consumption of potentially erosive beverages by school children.

In summary, the data from this study indicate that a subgroup of school children exists with a high frequent intake of potentially erosive drinks. The consumption pattern of erosive beverages drinks is also related to age and gender. This information may be useful when developing dietary advice for the prevention of dental erosion, which is considered a priority area for future research (Fox, 2010).

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Chapter 4

Acidic candies affect saliva secretion rates and oral fluid acidity

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ABSTRACT

After the observation of a 9-year-old child with dental erosion in a pediatric dental practice, the erosive potential of acidic candies was investigated in a 4-, an 8-, and a 12-year-old child. The saliva secretion rate and the acidity of the oral fluid of these children were measured before, during and after consumption of several types of candies. Consumption of most types of candies was finished after 2 minutes approximately. During the 2 minutes, the saliva secretion rate increased to minimally 2 and maximally 3.5 mL/min, with a concomitant pH decrease to less than 5 and even to 4. These effects disappeared within 2 minutes, suggesting that frequent consumption of acidic candies may contribute to the development of dental erosion.

INTRODUCTION

Dental erosion is diagnosed more and more frequently in general dental practices, even in young children. International studies indicate that dental erosion is present in high percentages of young children. A German study reported that in children from 2- to 7-years-old the prevalence of dental erosion increased with age up to 32%, and in 13% of the children erosion into the dentine was detected (Wiegand *et al.*, 2006). In an epidemiological study in the United States, 41% of 12-year-old children had some level of dental erosion (Nuttall and Deery, 2002). In 1999, only 3% of the Dutch children had dental erosion but in a follow-up study in 2002 tooth wear was observed in no less than 23% of the 12-year-old children (van Rijkom *et al*., 2002; Truin *et al*., 2005). This illustrates that dental erosion is an increasing problem in young children. Therefore it is important that studies on dental erosion not only focus on consumption of soft drinks and fruit juices (van Nieuw Amerongen and Rietmeijer, 2002; van Nieuw Amerongen *et al*., 2004; Huysmans *et al*., 2006), but also on other risk factors especially products consumed by children like different types of acidic candy.

A recent study showed that children frequently use candy sprays and gels (Gambon *et al*., 2006). These sprays have been developed for primary school children to produce a fresh taste in the mouth all day. Especially candy sprays have a high acidity (pH< 2.05). A single application of candy spray decreases the pH of saliva to a value of approximately 4.0. The salivary pH remains low for several minutes and then returns to values over 6.0 (Gambon *et al*., 2006).

Because candy mainly consists of sugars and often has sticky characteristics, it has been considered to be primarily a risk factor for the development of caries. However, candy also contains organic acids such as citric acid, malic acid and fumaric acid for a fresh acid taste (Table 1). A recent *in vitro* study reported that homogenized candies dissolved in water resulted in pH-values below 4 (Davies *et al*., 2006). Therefore, the aim of the present study was to evaluate the erosive potential of acidic candies *in vivo*.

MATERIAL AND METHODS

Based on enquiries to a manufacturer of candy, we selected several types of candy that are frequently used by children (Table 1 and Figure 1). The effects of these types of candy on the saliva secretion rate and the salivary pH were measured in three children (age 4, 8 and 12 years). Permission was obtained from their parents and from the Medical Ethical Committee of the Vrije Universiteit (Amsterdam, the Netherlands).

Before the consumption of a candy, unstimulated whole saliva was collected in a plastic container for 5 minutes. Subsequently, chewing-stimulated whole saliva was collected for 5 minutes while the children chewed on a 5 x 5 cm piece of tasteless plastic paraffin film (Parafilm®, Pechiney Plastic Packaging Company, Chicago, IL, USA). The volume of collected saliva

Table 1. Candies investigated in this study and organic acids present in it.

Product:	Organic acids:
Winegum (Haribo Starmix ®)	Citric acid
Yellow chewy fruit candy (Maoam Starmix ®)	Citric acid
Red chewy gumball (Maoam Starmix ®)	Citric acid
Strawberry stripes (Maoam Starmix ®)	Citric acid, malic acid
Fruit gum peach (Haribo ®)	Citric acid, fumaric acid
Winegum: red/liquorice/strawberry (Haribo Kindermix ®)	Citric acid/citric acid/lactic acid

Figure 1. Acid containing candies investigated.

was determined gravimetrically (assuming 1 g=1 mL) and the pH values were measured with a pH-meter (PHM 240 Sentron 1001, Radiometer, Copenhagen, Denmark). Buffering capacity was defined as the final pH after addition of 1 mL of 5 mM HCl to 1 mL of chewing-stimulated whole saliva (van Nieuw Amerongen, 2004).

Each child tested the first 5 candies mentioned in Table 1. Almost all investigated candies contained glucose syrup, gelatine and colouring and flavouring agents. In addition, they contain one or more organic acids, primarily citric acid. The children chewed one piece of candy and during this time the salivary secretion rate (mL/min) and pH were determined. The time needed to consume the piece of candy was also registered. Subsequently, while candy was no longer present in the mouth, saliva was collected for an additional 3-5 minutes. The saliva secretion rate and salivary pH of these samples were also measured. Between testing different types of candy, the children rinsed their mouth with water extensively and had a five-minute break. In a similar way, one child tested the last candies (Haribo Kindermix®) mentioned in Table 1.

Table 2. Baseline salivary values of the three participating children.

	4 years	8 years	12 years
Unstimulated saliva			
Secretion rate (mL/min)	0.04	0.2	0.42
pH	6.7	6.4	6.6
Chewing stimulated saliva			
Secretion rate (mL/min)	0.18	0.46	1.1
pH	7.4	7.1	7.4
Buffering capacity (pH)	6.16	6.32	6.56

RESULTS

The salivary flow rate increased in relation to the age of the three children (Table 2). All three children had a high salivary buffering capacity (pH after addition of HCl > 6) (Table 2). Most of the 5 candies that were tested by all 3 children were consumed completely within two minutes (Figure 2). During this time, the salivary secretion rate increased to 2 - 3.5 mL/min, depending on the taste stimulus (Figure 3a). Concomitantly, the pH dropped to values below 4.8 and when strawberry stripes were consumed even to 4.1 (Figure 3b). When the candy was removed from the mouth, the salivary secretion rate returned to normal values within one to two minutes (Figure 4a). The salivary pH also returned to baseline values (6.7 to 7.2) within a few minutes (Figure 3b).

Figure 4 shows the different effects on the salivary flow rate and the pH of three types of candies from the Haribo Kindermix®, tested by one child. Remarkable is the observed high increase in saliva secretion rate during consumption of the strawberry-flavoured candy (5.4 mL/min) (Figure 4a), with a concomitant large drop in salivary pH to 4.4 (Figure 4b). Probably this type of candy contains high levels of acid, in addition to the strawberry flavour. During the

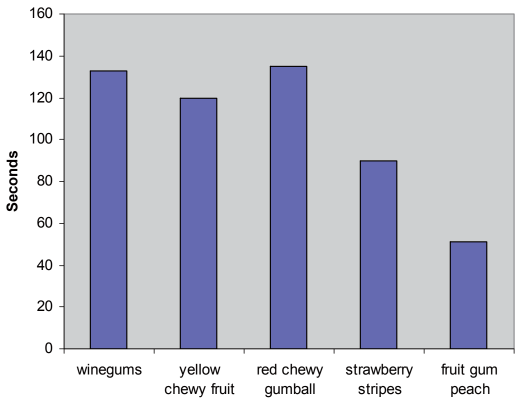

Figure 2. The average time to consume the candies studied (n = 3).

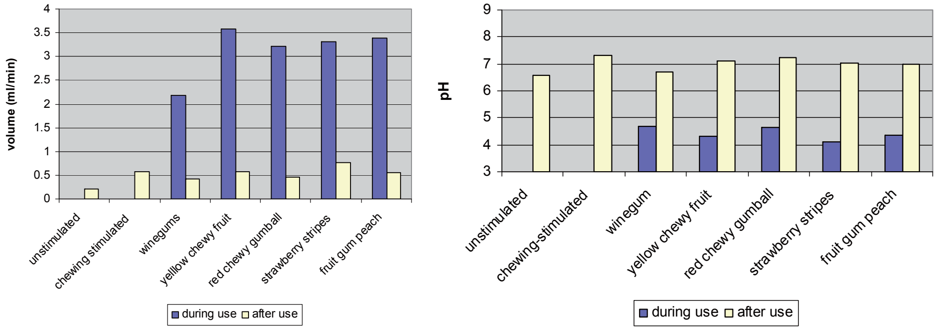

Figure 3. The average salivary secretion rate (a) and pH (b) during and after consumption of candy, compared to unstimulated and chewing-stimulated saliva (n = 3).

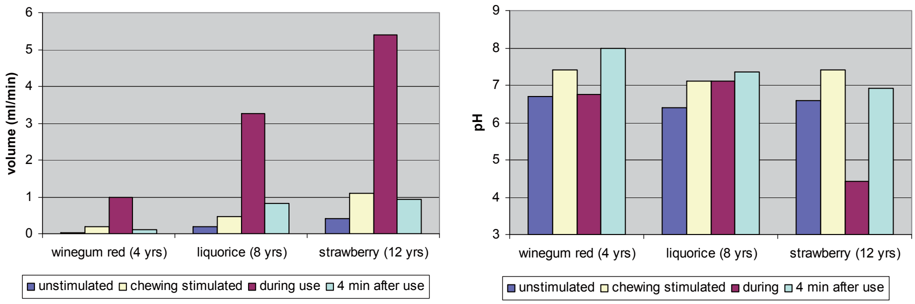

Figure 4. The salivary secretion rate (a) and pH (b) before, during and 4 minutes after use of red, liquorice or strawberry winegums (Haribo Kindermix®).

consumption of the red wine gum and liquorice wine gum, the pH of saliva remained neutral. The liquorice wine gum also stimulated the salivary flow rate considerably (3.3 mL/min).

DISCUSSION

Although only three children participated in this study, the results suggest that frequent use of candy may contribute to the development of dental erosion at a young age.

With regard to the increase in salivary flow rate of the three children, it should be mentioned that the measured salivary flow rates of the youngest child were very low. Possibly the accurate determination of the salivary flow rate in very young children is difficult, because it is hard for them to follow the instructions. E.g., a part of the saliva may have been swallowed instead of expectorated.

The pH of the oral fluid, however, can be measured reliably in very young children. The pH of unstimulated saliva of the children examined was slightly lower than the average values 6.8 - 7.0 of adults (van Nieuw Amerongen, 2004). On the other hand, no difference in pH of stimulated saliva was observed compared to the average values of 7.0 - 7.4 in adults, although the salivary secretion rates of the two youngest children were very low.

All candies contained citric acid, malic acid and/or fumaric acid (Table 1). They caused an increase of the salivary flow rate to 6 mL/min and a strong drop in salivary pH, in some cases even to 3.6. The strawberry-flavoured winegum from the Haribo Kindermix® was a remarkably strong stimulus for saliva secretion (Figure 4a). Previously, this has also been reported for candy sprays with strawberry flavour (Gambon *et al.*, 2006). The effect of the strawberry winegum on the salivary pH is probably the result of the amount of acid in this candy and not of the added fruit flavour, because the addition of strawberry flavour to fruit tea has no effect on the pH of the oral fluid (van Nieuw Amerongen *et al.*, 2004).

After consumption of the candies, the salivary secretion rate as well as the pH returned rapidly to normal levels (Figures 3 and 4). Remarkably, in the youngest child the pH decreased the least and restored to a value even higher than the chewing-stimulated baseline value. Nevertheless, his buffer capacity was not increased compared with the other two children.

Our results show that during consumption of candy the salivary pH decreases rapidly to values below 5.5, so that erosion of teeth could occur. When consumption remains limited to a single piece of candy, the length of the acid attack is probably too short for damage to occur. However, frequent use of candies increases the risk of enamel demineralisation. Therefore, it is recommendable that consumption of candy by children is limited as much as possible. The risk of dental erosion can be reduced by keeping candies in the mouth as short as possible and by rinsing the mouth with water after use. In addition, the risk of developing dental erosion could be further reduced by application of a fluoride varnish (Vieira *et al*., 2006).

Nevertheless, it seems desirable that candy packages mention that consumption of acidic candy can cause dental erosion and give information about the possible consequences. Manufacturers should also be stimulated to develop new toothfriendly candies, similar to the development of toothfriendly drinks for children (Amaechi and Higham, 2005; Young, 2005; Jandt, 2006).

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Chapter 5

The erosive potential of lollipops

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ABSTRACT

Aim: To determine the erosive potential of several commercially available lollipops and the protective effect of saliva.

Methods: The erosive potential of lollipops was determined *in vitro* by measuring the pH and neutralisable acidity. Subsequently, 10 healthy volunteers tested different types of lollipops. Whole saliva was collected 5 minutes before, 15 minutes during and 10 minutes after consumption. Salivary flow rate and pH were determined.

Results: Fruit-flavoured and cola-flavoured lollipops have a very low pH (2.3 - 2.4). Yogurt-containing and salmiak(salty liquorice)-flavoured lollipops have much higher pH values (3.8 - 4.7). The neutralisable acidity of 1 gram of lollipop showed a large variation from < 200 μL to > 1700 μL 0.1 M NaOH. *In vivo*, lollipops induced 2.5- to 4.7-fold increase in salivary flow rate with a concomitant drop in salivary pH. Consumption of fruit-flavoured and cola-flavoured lollipops resulted in a decrease in salivary pH below pH 5.5. With strawberry yogurt and salmiak lollipops, the salivary pH values remained above this critical value. The volunteers did not report significant differences in preferences for the lollipops.

Conclusions: Lollipops differ considerably in erosive potential, with fruit-flavoured and cola-flavoured lollipops having the highest erosive potential. This information is of use for clinicians counseling juvenile patients with dental erosion.

INTRODUCTION

Dental erosion is a pathologic, chronic localized loss of dental hard tissue that is chemically etched away from the tooth surface by acid and/or chelation without bacterial involvement (ten Cate and Imfeld, 1996). In the United States and the rest of the Western World, the prevalence of dental erosion is high in children and young adolescents, and the prevalence seems to be increasing (Deery *et al*., 2000; Linnett and Seow, 2001; Nunn *et al*., 2003; Dugmore and Rock, 2004; Jaeggi and Lussi, 2006; Kazoullis *et al*., 2007; El Aidi *et al*., 2008).

Although the etiology of dental erosion is multifactorial, it is assumed that dietary sources of acids are the major risk factor in this age group. Several studies have shown a strong relationship between the presence of dental erosion and a high level of consumption of cola-type and other flavoured carbonated beverages (Nunn *et al*., 2003; Dugmore and Rock, 2004; Al-Dlaigan *et al*., 2001; Jensdottir *et al*., 2004). Soft drinks contain acids such as phosphoric, citric and other acids as ingredients, and their pH is often less than 4.0 (Järvinen *et al*., 1990; Lussi *et al*., 2004; Moynihan, 2002).

Solid acidic candies also contain organic acids like citric acid and malic acid to develop the characteristic sour flavour. Homogenized sour sweets dissolved in water decreased the pH to values ranging from 2.3 to 3.1 (Davies *et al*., 2008). Incubation of human enamel in these sour sweet solutions *in vitro* for one hour induced significant loss of surface enamel (Davies *et al*., 2008). Sucking on this type of acidic candies the pH of whole-mouth saliva decreased to approximately 4.5 (Jensdottir *et al*., 2005 and 2007), well below the pH-value of 5.5 that has generally been adopted as the critical value below which hydroxyapatite dissolves (Ericsson, 1949; Larsen and Pearce, 2003). When tested *in situ*, sucking an acidic sugarfree lozenge was also capable to reduce the Knoop surface microhardness of human enamel (Lussi *et al*., 1997). Taken together, this suggests that consumption of acidic candies can contribute to the development of dental erosion, especially in individuals with low salivary flow rates and low salivary buffer capacity (Lussi *et al*., 1997).

During consumption of lollipops, this type of candy is usually kept in the mouth for a relatively long time. Since no information is available on the erosive potential of lollipops and the protective role of saliva, we investigated the erosive potential of a number of commercially available lollipops both *in vitro* and *in vivo*.

MATERIAL AND METHODS

For the *in vitro* experiment, ten different flavoured lollipops of 12 grams were chosen: apple, orange, strawberry, cherry, cola, cola-lemon, strawberry yogurt, berries yogurt, peach yogurt and salmiak (Chupa Chups, Cornellà de Llobregat, Spain). Each lollipop was homogenized with a mortar and pestle, and 1 g of the resultant powder was dissolved in 2 mL of deionised water (Davies *et al*, 2008). Subsequently, the erosive potential of each solution was assessed by measuring the pH and neutralisable acidity ('buffer capacity'). The pH was determined with an electronic pH meter (PHM 240 Sentron 1001, Radiometer, Copenhagen, Denmark), calibrated with reference buffers of pH 4.00 and pH 7.00 (Sigma-Aldrich, St. Louis, MO, USA). Neutralisable acidity of the lollipop solutions was determined by stepwise addition of 100 μL 0.1 M NaOH till a pH > 7.0 was obtained.

The effect of lollipops on saliva secretion rate and pH was investigated in ten healthy volunteers, 34 ± 13 years of age, fully dentate (≥ 28 teeth), without active caries and not suffering from xerostomia, taste or masticatory dysfunctions. The volunteers were instructed to abstain from smoking, eating, drinking and tooth brushing at least 1 h before the experiments (Hoek *et al*., 2002).

The protocol was approved by the Medical Ethical Committee of the Vrije Universiteit (Amsterdam, the Netherlands) and prior to the experiment all volunteers gave informed consent.

Six different lollipops, selected on basis of differences in pH and neutralisable capacity, were tested by each volunteer in randomized order on different days. Each experimental session consisted of an initial collection of unstimulated whole saliva for 5 minutes (Bosch *et al*., 1996). Subsequently, a lollipop was placed in the buccal pouch and whole saliva was collected in 1 minute intervals for a total period of 15 minutes, after which the stimulus was removed and saliva was collected at 1 minute intervals for an additional 10 minutes (post-stimulated). Finally, the preferences for the different lollipops were assessed with a 100 mm visual analogue scale (VAS, nasty – delicious) (Bots *et al*., 2004). Saliva secretion rates were determined gravimetrically (assuming 1 gram = 1 mL) and the salivary pH was measured as described above. In an additional experiment, the volunteers also received a strawberry-flavoured lollipop while they were instructed to suck actively on this lollipop. Then the procedure of the determination of the pH and salivary secretion was repeated.

STATISTICS

Differences in salivary pH and secretion rate between experimental conditions were explored with analysis of variance (ANOVA) for repeated measures. The statistical analysis was performed using the statistical software package SPSS version 12.0.1 (SPSS Inc., Chicago, IL, USA). All levels of significance were set at $p < 0.05$.

RESULTS

The pH of the solution containing the dissolved fruit-flavoured lollipops (apple, orange, strawberry and cherry) ranged from 2.29 to 2.40. The solutions containing cola-and cola-lemon-flavoured lollipops had comparable pH values (2.24 and 2.44, respectively). The pH of the yogurt containing lollipops was much higher, ranging from 3.80 to 4.28. The highest pH was observed for the salmiak-flavoured lollipop (4.70).

The neutralisable acidity results are presented in Figure 1. The salmiak lollipop has a very low neutralisable acidity (< 200 μL 0.1 M NaOH), in contrast to the fruit and cola lollipops which had neutralisable acidities > 1700 μL. Yogurt containing lollipops and the cola-lemon lollipop have intermediate values (1000 – 1500 μL).

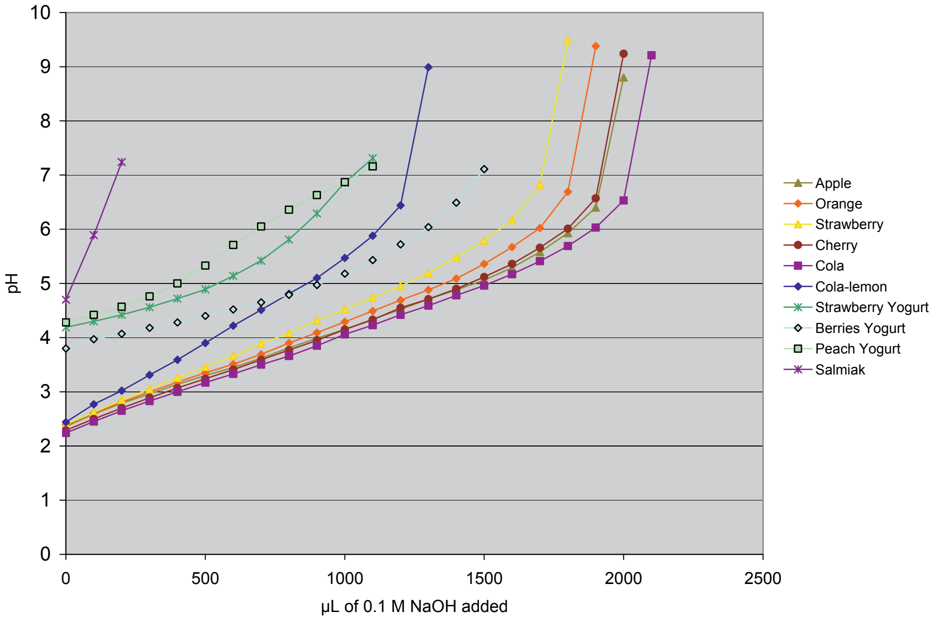

Figure 1. Neutralisable acidity of 1 gram of ten different lollipops, determined by stepwise addition of 100 μL of 0.1 M NaOH until a pH > 7 was reached.

In vivo, placement of a lollipop in the buccal pouch induced an immediate increase in salivary flow rate (Figure 2). This increase in salivary flow rate varied between 2.5 and 4.7-fold during the first minute, and remained constant during the whole period of 15 minutes while the lollipop was present. The strawberry yogurt lollipop gave significantly less stimulation of the salivary flow than the strawberry-, cherry- and cola-flavoured lollipops ($p = 0.007$, 0.005 and 0.020, respectively).

With the exception of the salmiak-flavoured lollipop, all lollipops induced a significant decrease of the salivary pH within 2-4 minutes, which remained constant till the lollipop was

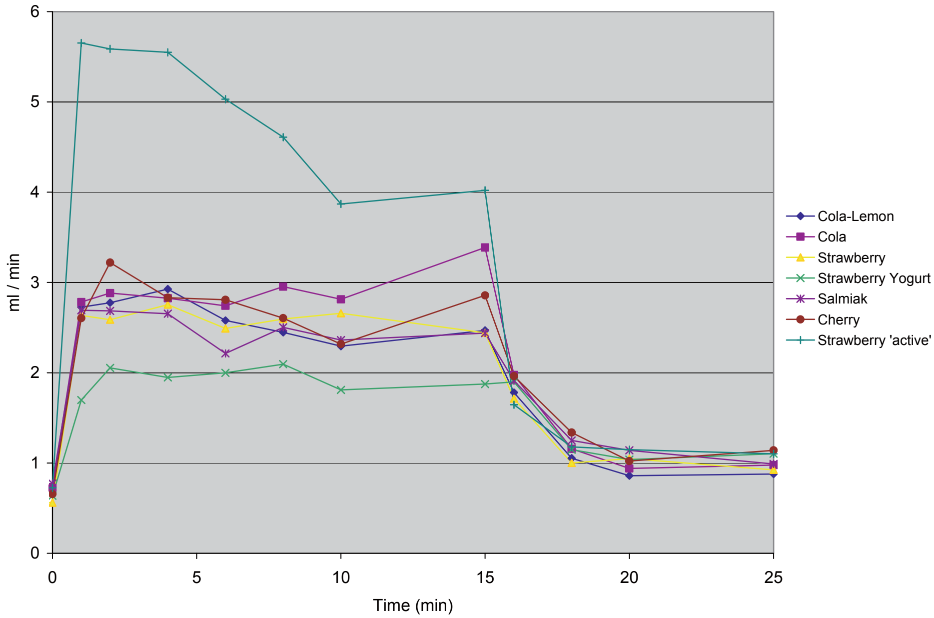

Figure 2. Mean salivary flow rate before, during and after use of six different lollipops (n =10). During the period 0 to 15 minutes, the lollipops were kept in the buccal pouch. A strawberry-flavoured lollipop was also actively sucked during the period 0 - 15 minutes ('active').

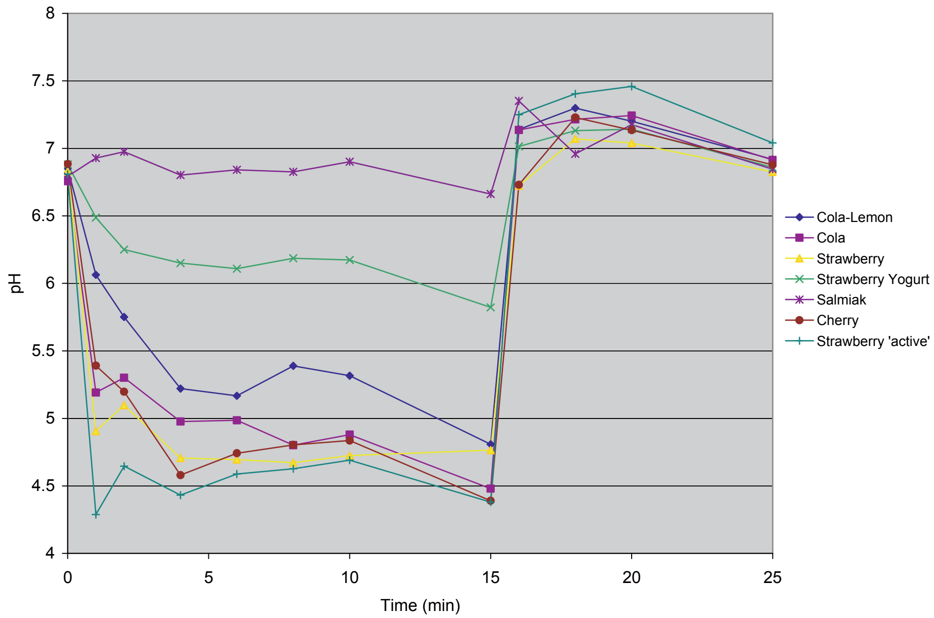

Figure 3. Mean salivary pH before, during and after use of six different lollipops (n =10). During the period 0 to 15 minutes, the lollipops were kept in the buccal pouch. A strawberry-flavoured lollipop was also actively sucked during the period 0 - 15 minutes ('active').

removed from the buccal pouch (Figure 3). For the strawberry-, cherry-, cola- and cola-lemon-flavoured lollipops the salivary pH dropped below the critical value of 5.5 for the majority of time. The strawberry yogurt lollipop induced a smaller drop in salivary pH, which remained above the critical value. The salivary pH during consumption of the strawberry yogurt and the salmiak-flavoured lollipop were both significantly different from all other lollipops tested ($p < 0.0005$). As soon as the lollipops were removed from the mouth, the salivary pH values returned to normal within 1 minute.

The volunteers did not report significant differences in preferences for the lollipops (data not shown). Actively sucking a strawberry-flavoured lollipop induced a significantly higher salivary flow rate when the same lollipop was placed passively in the buccal pouch ($p < 0.0005$, Figure 2). Both conditions also yielded different salivary pH. Actively sucking on a lollipop caused a larger drop in salivary pH than the passive condition during the first minute. The post-stimulation pH-values however were significant higher (Figure 3).

DISCUSSION

The aim of this study was to compare the erosive potential of several lollipops. Fruit flavoured- and cola-flavoured lollipops tested in this study were highly acidic, suggesting that they contain high levels of citric acid and/or malic acid. Their initial pH values ranged from 2.29 – 2.44, far below the pH-value of 5.5 that has generally been adopted as the critical value below which hydroxyapatite may dissolve (Ericsson, 1949; Larsen and Pearce, 2003). However, the erosive potential of a lollipop does not exclusively depend on the pH, but is also strongly influenced by its neutralisable acidity ('buffer capacity'). The greater the neutralisable acidity of the lollipop, the longer it will take for saliva to neutralize it (Lussi *et al.*, 2004). The fruit-flavoured ones and the cola lollipops not only have a low pH but also have the highest buffer capacity (Figure 1), which suggests that they have a much higher erosive potential than the yogurt containing and salmiak-flavoured lollipops.

All lollipops stimulate the salivary flow immediately after they have been introduced into the mouth (Figure 2). The high salivary flow rate obtained while actively sucking the strawberry lollipop is comparable to the increase previously reported for active sucking acidic candies (Jensdottir *et al.*, 2005 and 2007). In spite of the protective effects from the salivary buffer capacity and acid clearance (Davies *et al.*, 2008; Jensdottir *et al.*, 2007; Hunter *et al.*, 2008), the fruit- and cola-flavoured lollipops decreased the intraoral pH values considerably below 5.5, indicating the erosive potential of lollipops *in vivo*. This is in agreement with similar studies showing the erosive potential of solid acidic candies (Davies *et al.*, 2008; Jensdottir *et al.*, 2005 and 2007; Lussi *et al.*, 1997; Bibby and Munsdorf, 1975).

Our *in vivo* results are based on the use of lollipops by healthy adult volunteers. However, lollipops are frequently used by children and the volume of saliva in children is smaller than in adults (Crossner, 1984; Watanabe and Dawes, 1990). Therefore, in children the same lollipop in relation to the smaller amount of saliva may result in even lower salivary pH values. The size of the lollipop may also play a role in the risk for developing dental erosion, since the mass of acidic lozenges was related to the level of enamel softening *in situ* (Lussi *et al*., 1997). In this respect, it seems disturbing that the strawberry lollypop tested is even available in an approximately 800 grams version.

The use of lollipops over a long period of time may exacerbate its erosive potential, as the longer the teeth are exposed to acid, the longer the period of time for erosion to occur and the less time for remineralisation (Lussi *et al*., 2004; Moynihan, 2002). Differences seem to exist in susceptibility of deciduous and permanent dentition to erosion by low pH drinks and solid acidic candy. In general, erosion of enamel was greater in the deciduous tissue, especially with increased frequency of consumption (Davies *et al*., 2008; Hunter *et al*., 2000a and b). In combination with the reduced dimensions, this makes the deciduous dentition more susceptible to the long-term acid attack by lollipops.

Yogurt containing lollipops seem to have no or a much smaller erosive potential. Not only were their *in vitro* pH values much higher than that of fruit-flavoured lollipops (Figure 1), but during the 15 minutes of consumption the strawberry yogurt lollipop also induced a smaller drop in salivary pH, which remained above the critical value of 5.5 (Figure 3). Furthermore, it has to be noted that the higher calcium content of the strawberry yogurt lollipop will lower the critical pH value at which dissolution of hydroxyapatite occurs. E.g. addition of calcium to erosive drinks and lozenges decreased the critical pH below which hydroxyapatite dissolved in acid (Jensdottir *et al*., 2007; Dawes, 2003), and reduced the enamel softening of low pH sports drinks and juices (Lussi and Jaeggi, 2008).

In summary, our study shows that lollipops differ considerably in erosive potential, with fruit-flavoured and cola-flavoured lollipops having a relatively high risk for developing dental erosion. Health-care professionals, juvenile patients and their parents should be informed that (excessive) use of these lollipops may cause dental erosion.

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Chapter 6

The erosive potential of jawbreakers

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ABSTRACT

Objectives: To explore the consumption pattern of a specific type of acidic solid candy, the so-called jawbreakers, by primary school children and determine the erosive potential of this candy *in vivo*.
Methods: A questionnaire about jawbreaker consumption was distributed among 10- to 12-year-old children (n=302). Subsequently, nineteen healthy volunteers tested four different jawbreakers *in vivo*. Whole saliva was collected 5 minutes before, 3 minutes during and 11 minutes after consumption. Salivary flow rate and pH were determined.
Results: Two-thirds of the children reported a history of jawbreaker consumption, 18% during the last week. More than half of the children estimated their average time for consumption of one jawbreaker to be more than 15 minutes. *In vivo*, the jawbreakers induced 8.6- to 13.9-fold increase in salivary flow rate. Sucking on sour, jumbo and strawberry jawbreakers induced a drop in salivary pH to values below pH 5.5. During consumption of fireball jawbreakers, the intraoral pH hardly changed.
Conclusions: Jawbreakers are frequently used by children, who keep this candy in their mouth for a long time. Jawbreakers differ considerably in erosive potential, with sour and jumbo jawbreakers > strawberry jawbreaker >> fireball jawbreaker. This information is of use for clinicians counseling juvenile patients with dental erosion.

INTRODUCTION

Dental erosion is a pathologic, chronic localized loss of dental hard tissue due to chemical dissolution of the tooth surface by acid and/or chelating agents without bacterial involvement (ten Cate and Imfeld, 1996). In the United Kingdom and the rest of the Western World, the prevalence of dental erosion is high in children and young adolescents, and the prevalence seems to be increasing (Deery *et al*., 2000; Linett and Seow, 2001; Nunn *et al*., 2003; Dugmore and Rock, 2004; Jaeggi and Lussi, 2006; Kazoullis *et al*., 2007; El Aidi *et al*., 2008).

The etiology of dental erosion is multifactorial, but it is assumed that dietary sources of acids are the major risk factor in this age group. Several studies have shown a strong relation between the presence of dental erosion and a high level of consumption of cola-type and other flavoured carbonated beverages (Nunn *et al*., 2003; Dugmore and Rock, 2004; Al-Dlaigan *et al*., 2001; Jensdottir *et al*., 2004). Soft drinks contain acids such as phosphoric, citric and other acids as ingredients, and their pH is often less than 4.0 (Järvinen and Rytömaa, 1990; Lussi *et al*., 2004; Moynihan, 2002).

Solid acidic candies also contain organic acids such as citric acid and malic acid to develop the characteristic sour flavour, and therefore are potentially erosive. Homogenized sour sweets dissolved in water decreased the pH to values ranging from 2.3 to 3.1 (Davies *et al*., 2008). Incubation of human enamel in these acid solutions *in vitro* for one hour induced significant loss of surface enamel (Davies *et al*., 2008). Sucking this type of acidic candies decreased the pH of whole-mouth saliva to approximately 4.5 (Jensdottir *et al*., 2005 and 2007), well below the pH-value of 5.5 that has generally been adopted as the critical value below which hydroxyapatite dissolves (Ericsson, 1949; Larsen and Pearce, 2003). It was found that the Knoop surface microhardness of human enamel decreased *in situ*, sucking an acidic sugar-free lozenge (Lussi *et al*., 1997). Taken together, this suggests that consumption of acidic candies can contribute to the development of dental erosion, especially in individuals with low salivary flow rates and low salivary buffer capacity (Lussi *et al*., 1997).

Jawbreakers consist of several hard layers of candy around a bubble gum centre (Figure 1). They are usually round with a diameter between 1 and 3 cm. As their name suggests, they are difficult to bite, and therefore usually consumed by sucking or licking. Jawbreakers are mainly consumed by primary school children. As jawbreakers dissolve slowly, the children will keep them in the mouth for a relatively long time. The aim of the present study was twofold. Firstly, to explore the frequency and characteristics of jawbreaker consumption among school children. Secondly, to examine the erosive potential of a number of commercially available jawbreakers *in vivo* by measuring their effect on saliva pH during and after consumption.

Figure 1. Jawbreakers consist of hard layers of candy around a bubble gum centre, usually with a diameter comparable to a one pound coin.

METHODS

A written questionnaire was distributed in October 2008 among school children between 10 and 12 years of age from three different primary schools in Rotterdam, the Netherlands. The questionnaire included questions with regard to age, gender, whether the child had ever consumed a jawbreaker, jawbreaker consumption during the previous week and the way and estimated time jawbreakers were kept in the mouth. Participation was on a voluntary base, and the questionnaire was distributed and immediately returned after completing by 302 children (143 boys, 148 girls, 11 children did not report their gender) with the response rate of 100%.

The effects of jawbreakers on saliva secretion rate and pH were investigated in 19 healthy volunteers between 20 and 25 years of age, fully dentate (≥ 28 teeth), without active caries and not suffering from xerostomia, taste or masticatory dysfunctions. The protocol was approved by the Medical Ethical Committee of the Vrije Universiteit (Amsterdam, the Netherlands). Prior to the experiment all volunteers gave informed consent. The volunteers were instructed to abstain from smoking, eating, drinking and tooth brushing at least 1 hour before the experiments (Hoek *et al*., 2002).

Four different jawbreakers (Table 1) were tested by each volunteer in randomized order on different days. Each experimental session consisted of an initial collection of unstimulated whole saliva for 5 minutes (Bosch *et al*., 1996). Subsequently, a jawbreaker was placed in the mouth and whole saliva was collected in 1 minute intervals for a total period of 3 minutes while the volunteer sucked on the jawbreaker. Subsequently, the jawbreaker was removed from the mouth and saliva was collected at 1 or 2 minute intervals for an additional 11 minutes (post-stimulus). The preferences for the different jawbreakers were assessed with a 100 mm visual analogue scale (VAS, nasty – delicious) (Bots *et al*., 2004). Saliva secretion rates were determined gravimetrically (assuming 1 gram = 1 mL). The salivary pH was determined with an electronic pH meter (PHM 240 Sentron 1001, Radiometer, Copenhagen, Denmark), calibrated each morning with reference buffers of pH 4.00 and pH 7.00 (Sigma-Aldrich, St. Louis, MO, USA).

Table 1. Characteristics of the tested jawbreakers and the type of acid mentioned on the product label. Weight and diameter are the mean of five different jawbreakers.

Product	Weight (gr)	Diameter (mm)	Acid	Manufacturer
Strawberry jawbreaker	8.6	24	citric acid	Zed Candy, Dublin, Ireland
Jumbo jawbreaker	21.1	31	citric acid	Zed Candy, Dublin, Ireland
Fireball jawbreaker	8.6	23	citric acid	Zed Candy, Dublin, Ireland
Sour jawbreaker	8.3	23	citric acid	Zed Candy, Dublin, Ireland

STATISTICS

Gender effects on jawbreaker consumption were explored with Chi-Square tests. Differences in preferences, salivary pH and secretion rate between experimental conditions were explored with analysis of variance (ANOVA) for repeated measures. The statistical analysis was performed using the statistical software package SPSS version 15.0.1 (SPSS Inc., Chicago, IL, USA). All levels of significance were set at $p < 0.05$.

RESULTS

Two hundred of the 302 children (66.2%) reported a history of jawbreaker consumption. A history of jawbreaker consumption was significantly more frequently reported by boys than by girls (72.7% versus 60.1%, $p = 0.023$). Eighteen percent of the children reported that they had used one or more jawbreakers during the previous week. For consumption during the previous week, no gender effect was observed (18.5% for boys versus 17.4% for girls).

During consumption, children usually place the jawbreakers in the buccal pouch (52.3% of the children with a history of jawbreaker consumption) or suck on it (50.3%). Licking the jawbreaker (8.8%) or biting it into pieces (13.5%) was much less frequently reported. A gender effect was only observed for licking jawbreakers, which was more frequently reported by girls than by boys (14.6% versus 3.8%, p = 0.009). More than half of the children estimated their mean time for consumption of a jawbreaker to be more than 15 minutes (Table 2). About 10% of the children who consumed jawbreakers reported that they sometimes play a game with other kids to keep the jawbreaker in their mouth as long as possible. These games were more often reported by boys (12.7%) than by girls (7.9%) but this difference did not reach statistical significance.

Table 2. Estimated time for consumption of a jawbreaker by children (10-12 years)

	All (n=193)	Boys (n=104)	Girls (n=89)
< 15 minutes	41.5%	39.4%	43.8%
>15 minutes but < 30 minutes	34.7%	33.7%	36.0%
>30 minutes but < 60 minutes	12.4%	17.3%	6.7%
>60 minutes	8.3%	4.8%	12.4%
Not reported	3.1%	4.8%	1.1%

In vivo, sucking on a jawbreaker induced an immediate increase in salivary flow rate (Figure 2). This increase in salivary flow rate varied between 8.6- and 13.9-fold during the first minute, and remained significantly increased during the whole period of 3 minutes while the jawbreaker

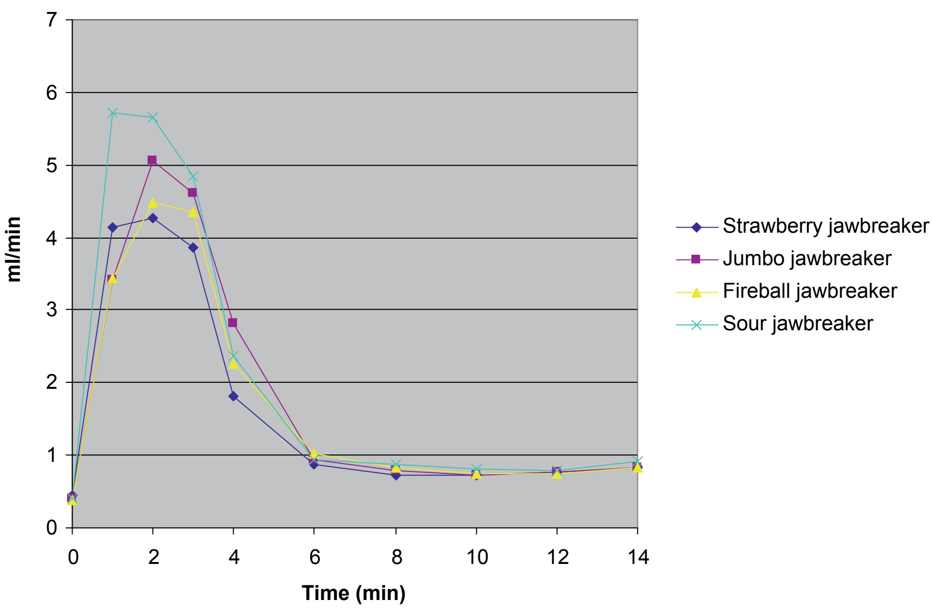

Figure 2. Mean salivary flow rate before, during and after use of four different jawbreakers (n =19). The test persons sucked actively on a jawbreakers to 3 minutes. Then the jawbreaker was taken out of the mouth.

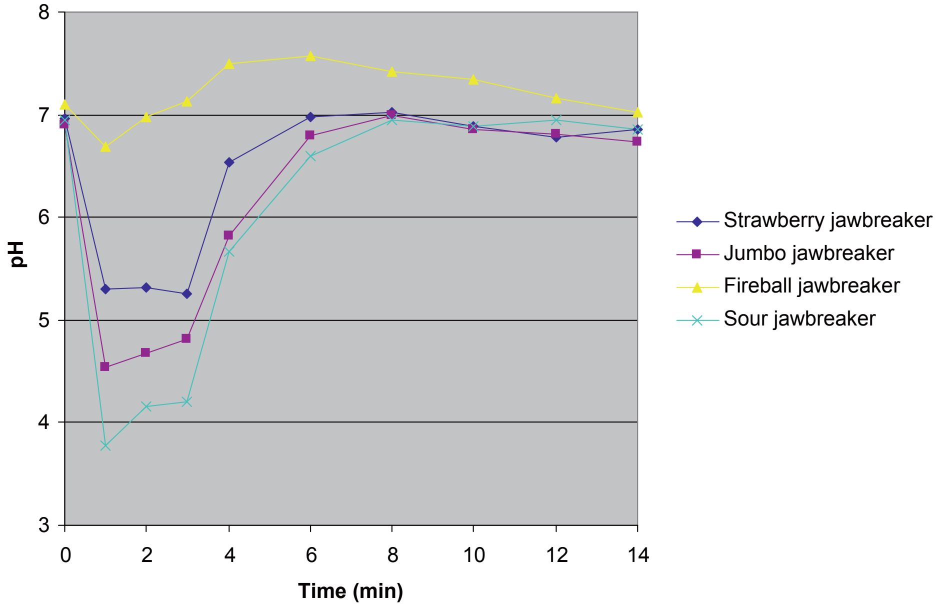

Figure 3. Mean salivary pH before, during and after use of four different jawbreakers (n =19). The test persons sucked actively on a jawbreaker to 3 minutes. Then the jawbreaker was taken out of the mouth.

was present in the mouth. During the first minute, the sour jawbreaker induced significantly more stimulation of the salivary flow than the other three jawbreakers.

With the exception of the fire jawbreaker, all jawbreakers induced a significant decrease of the salivary pH within 1 minute, which remained constant until the jawbreaker was removed from the mouth (Figure 3). For the jumbo and sour jawbreaker, the salivary pH dropped to values far below pH 5.0. The strawberry jawbreaker induced a smaller drop in salivary pH to values around 5.3.

For each jawbreaker, the salivary flow rate dropped considerably within several minutes after it was removed from the mouth, but still remained significantly increased during the whole post-stimulus period when compared to the baseline values. After removal of the strawberry, jumbo- and sour jawbreakers from the mouth, the salivary pH values returned to baseline values within 1 minute. After removal of the fireball jawbreaker a small but significant transient increase in salivary pH above the baseline values was observed. The fireball jawbreaker was appreciated less than the other jawbreakers, but this difference did not reach statistical significance (Table 3).

Table 3. Appreciation of four different jawbreakers by healthy volunteers, assessed with a 100 mm visual analogue scale (VAS, nasty – delicious). Data are expressed as mean ± SD (n=19).

	VAS-score (mm)
Strawberry jawbreaker	62.5 ± 21.7
Jumbo jawbreaker	57.7 ± 23.5
Fireball jawbreaker	44.6 ± 34.5
Sour jawbreaker	64.1 ± 25.3

DISCUSSION

The results from this study show that primary school children frequently use jawbreakers. They keep this type of hard candy in their mouth for prolonged times, and some kids even compete with other children to keep a jawbreaker in the mouth as long as possible.

Immediately after the jawbreakers were introduced into the mouth, each tested variant stimulated the salivary flow rate (Figure 2), to a comparable extent as acidic candies or lollipops (Jensdottir *et al*., 2007; Brand *et al*., 2009). In spite of the protective effects of saliva (buffering and dilution) (Davies and Hunter, 2008; Jensdottir *et al*., 2005; Hunter *et al*., 2008), the jumbo jawbreaker and the sour jawbreaker decreased the intraoral pH values considerably below the pH-value of 5.5, the value that has generally been adopted as the critical value below which hydroxyapatite dissolves (Ericsson, 1949; Larsen and Pearce, 2003), indicating the erosive potential of these jawbreakers *in vivo*. This is in agreement with similar studies showing the erosive potential of other solid acidic candies (Davies *et al*., 2008; Jensdottir *et al*., 2005 and 2007; Lussi *et al*., 1997; Brand *et al*., 2009; Bibby and Mundorff, 1975).

The strawberry jawbreaker gave a smaller decrease in intraoral pH, suggesting a smaller erosive potential. This is not a general characteristic for strawberry-flavoured candy. Previously it has been reported that strawberry-flavoured lollipops have similar erosive potential *in vivo* as lollipops with other flavours (Brand *et al.*, 2009). After intraoral application of a single dose of candy spray, the lowest pH values were observed for two strawberry-flavoured variants (Gambon *et al*., 2009).

According to the product label, all tested jawbreakers contained citric acid. However, the observed large differences in decrease of intraoral pH during consumption suggest considerable differences in concentration of citric acid. Citric acid is an organic acid with pronounced erosive properties. It lowers the pH of saliva and therefore promotes dissolution of enamel. Also at neutral pH the citrate anion, acting as a chelator of calcium ions enhances the demineralisation of dental enamel. This means that the demineralising effect of citric acid may even continue after the pH at the tooth surface has normalized (Järvinen and Rytömaa, 1990; Hunter *et al*., 2008; Lussi and Jaeggi, 2008).

Our *in vivo* results are based on the use of jawbreakers by young adult volunteers. However, jawbreakers are mainly used by children and the volume of saliva in children is smaller than in adults (Crossner, 1984; Watanabe and Dawes, 1990). Therefore, in children the same jawbreaker may result in even lower salivary pH values. The size of the jawbreaker will also determine its erosive potential, since the mass of acidic lozenges was related to the level of enamel softening *in situ* (Lussi *et al.*, 1997). The use of acidic jawbreakers for a long period of time may exacerbate its erosive potential, as the longer the teeth are exposed to acid, the longer the period of time for erosion to occur and the less time for remineralisation (Lussi and Jaeggi *et al*., 2004; Moynihan, 2002). In this respect, it seems disturbing that a sour jawbreaker is available in an approximately 80 grams version with a diameter of 48 mm, which is advertised as "do you dare take the eight hour challenge" (www.zedcandy.com, 2009).

Compared to the permanent dentition the deciduous dentition is more susceptible for erosive attacks, particularly with increased frequency of consumption (Davies *et al*., 2008; Hunter *et al*., 2000a and 2000b). In combination with the smaller dimensions, this makes the deciduous dentition more susceptible to the long-term acid attack by jawbreakers.

When the outer layers of hard candy are dissolved, the child will start chewing the bubble gum centre, presenting an additional threat to the enamel surface. The long-term exposure to acid will have softened the dental enamel, making it more prone for mechanical tooth wear due to attrition by the subsequent chewing of gum. It is well-recognized that such interactions between erosion and attrition can have a synergistic effect on tooth wear (Litonjua *et al*., 2003; Addy and Shellis, 2006).

CONCLUSION

In summary, our study shows that jawbreakers are frequently used by school children, who tend to keep this type of candy in their mouth for a long time. The tested jawbreakers differed considerably in erosive potential, with jumbo and sour jawbreakers having the most pronounced erosive properties. Health-care professionals, juvenile patients and their parents should be informed that (excessive) use of these jawbreakers may cause tooth wear.

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Chapter 7

The erosive potential of candy sprays

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*British Dental Journal 2009;**23**:206:E20*

ABSTRACT

Objective: To determine the erosive potential of seven different commercially available candy sprays *in vitro* and *in vivo*.
Methods: The erosive potential was determined *in vitro* by measuring the pH and titratable acidity. The salivary pH and flow rate were measured in healthy volunteers after administration of a single dose of candy spray.
Results: Candy sprays have an extremely low pH (1.9 - 2.3) and a titratable acidity between 0.2 and 0.4 M. *In vivo*, candy sprays induced a short-term 3.0 to 5.8-fold increase in salivary flow rate with a concomitant drop in salivary pH to values between 4.4 and 5.8.
Conclusion: All candy sprays tested have an erosive potential. This information is of use for clinicians counseling juvenile patients with dental erosion.

INTRODUCTION

Dental erosion has been defined as the physical result of a pathologic, chronic localized loss of dental hard tissue that is chemically etched away from the tooth surface by acid and/or chelation without bacterial involvement (ten Cate and Imfeld, 1996). In the United Kingdom, the prevalence of dental erosion is high in children and young adolescents, and the prevalence still seems to be increasing (Al-Dlaigan *et al*., 2001a and 2001b; Al-Malik *et al*., 2001; Bartlett *et al*., 1998; Deery *et al*., 2000; Dugmore and Rock, 2003 and 2004; Jones and Nunn, 1995; Millward *et al*., 1994a; Millward *et al*., 1994b; Milosevic *et al*., 1994; Milosevic *et al*., 1997; Nunn *et al., 2003*; Williams *et al*., 1999). Although the etiology of dental erosion is multifactorial, it is assumed that dietary sources of acids are the major risk factor in this age group. Several studies found an association between the presence of dental erosion and a high level of consumption of cola-type and other flavoured carbonated beverages (Dugmore and Rock, 2004; Millward *et al*., 1994a; Milosevic *et al*., 1994; Milosevic *et al*., 1994; Al-Dlaigan *et al*., 2001; Jensdottir *et al*., 2004; Johansson *et al.,* 1997). Many soft drinks contain phosphoric, citric and other acids as ingredients, and their pH is often less than 4.0 (Järvinen *et al*., 1990; Lussi *et al*., 2004; Moynihan, 2002).

Solid acidic candies also contain organic acids such as citric acid, lactic acid or malic acid to give the characteristic sour taste. Homogenized candies dissolved in water decreased the pH to values below 4.0 (Davies *et al*., 2008). *In vivo* studies showed that sucking acidic candies decreased the salivary pH to 4.5 (Jensdottir *et al*., 2005 and 2007). Acidic candies were capable to soften enamel both *in vitro* and *in situ* (Bibby and Mundorff, 1975; Lussi *et al*., 1997). Taken together, this suggests that excessive consumption of acidic candies can contribute to the development of dental erosion, especially in individuals with low salivary flow rates and low salivary buffer capacity (Lussi *et al*., 1997).

A recently introduced type of acidic candy is the so-called candy spray, which has to be sprayed directly into the mouth (Figure 1). This gives an immediate sour-fresh taste and tingling feeling on the tongue. Candy sprays are very popular among primary school children. In the Netherlands, 31% of children between 4- to 8- years-old and 58% of children between 9- to

Figure 1. A child using a candy spray.

Figure 2. Erosion of occlusal surfaces in a 9-year-old girl with a history of excessive use of candy spray.

12-years-old reported they had used candy sprays (Gambon *et al*., 2006). In the same study, a 9-years-old girl was presented with severe erosion of the occlusal surfaces attributed to excessive use of candy spray, indicating that consumption of candy sprays has a potential risk for dental erosion (Figure 2). Since several types and tastes of candy sprays are available in the United Kingdom, the aim of this study was to compare the erosive potential of a number of commercially available candy sprays both *in vitro* and *in vivo*.

METHODS

Seven candy sprays, available to the general public, were chosen for this study (Table 1, Figure 3). First, the pH of each candy spray was determined with an electronic pH meter (PHM 240 Sentron 1001, Radiometer, Copenhagen, Denmark), calibrated each morning with reference buffers of pH 4.00 and pH 7.00 (Sigma-Aldrich, St. Louis, MO, USA). Titratable acidity of the candy sprays was determined by stepwise addition of 0.1 mL 0.25 M NaOH to 1 mL of candy spray till a pH > 7 was obtained. The volume of a single dose of each candy spray was determined gravimetrically (assuming 1 gram = 1 mL).

Table 1

Product	pH	Single dose (µL)	Acid	Distributor
Candy spray strawberry	1.99	145	citric acid	Starsweets International
Fruitti squirt strawberry	2.00	132	citric acid	Starsweets International
Magic spray strawberry	2.28	95	citric acid	Pemi Trade
Mega mouth spray strawberry	1.92	146	citric acid	Topps International LTD
Mega mouth spray orange	1.90	146	citric acid	Topps International LTD
Mega mouth spray blackcurrant	1.92	147	citric acid	Topps International LTD
Mega mouth spray apple	1.91	137	citric acid	Topps International LTD

Figure 3. The different types of candy sprays investigated in this study.

The effect of candy sprays on saliva secretion rate and pH were investigated in three healthy volunteers, 53 ± 9 years of age, fully dentate (≥ 28 teeth), without active caries and not suffering from taste abnormalities or xerostomia. The volunteers were instructed to abstain from smoking, eating, drinking and tooth brushing at least 1 h before the experiments (Hoek *et al*., 2002).

First, unstimulated whole saliva was collected for 5 minutes (Bosch *et al*., 1996). Next, in random order a single dose of each candy spray was administered on the tongue and whole saliva was collected in 1 minute intervals for a total period of 5 minutes. The saliva secretion rates were determined gravimetrically (assuming 1 gram=1 mL) and the salivary pH was measured as described above.

RESULTS

The pH values of the candy sprays are very low, ranging from 1.90 - 2.28 (Table 1). The results for the titratable acidity are presented in Figure 4. Most candy sprays tested have a titratable acidity between 0.2 - 0.4 M, but the Candy spray strawberry and the Fruitti squirt strawberry have an almost two-fold higher titratable acidity than the other candy sprays.

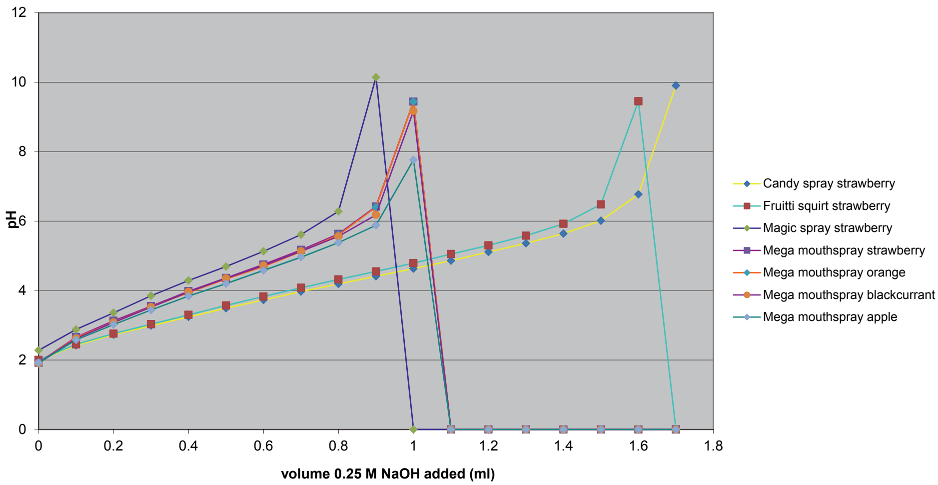

Figure 4. Determination of the titratable acidity in candy sprays.

The volume of a single dose is comparable for all candy sprays (range 132 – 147 µL), with the exception of Magic spray strawberry which produces a smaller volume (95 µL, see Table 1). Intraoral administration of a single dose of candy spray induced a transient 3.0 to 5.8-fold increase in salivary flow rate (Figure 5). The highest salivary flow rates were observed after use of the Candy spray strawberry and the Fruitti squirt strawberry, the lowest after the Magic spray strawberry. Concomitantly, the salivary pH dropped instantaneously to values between 4.4

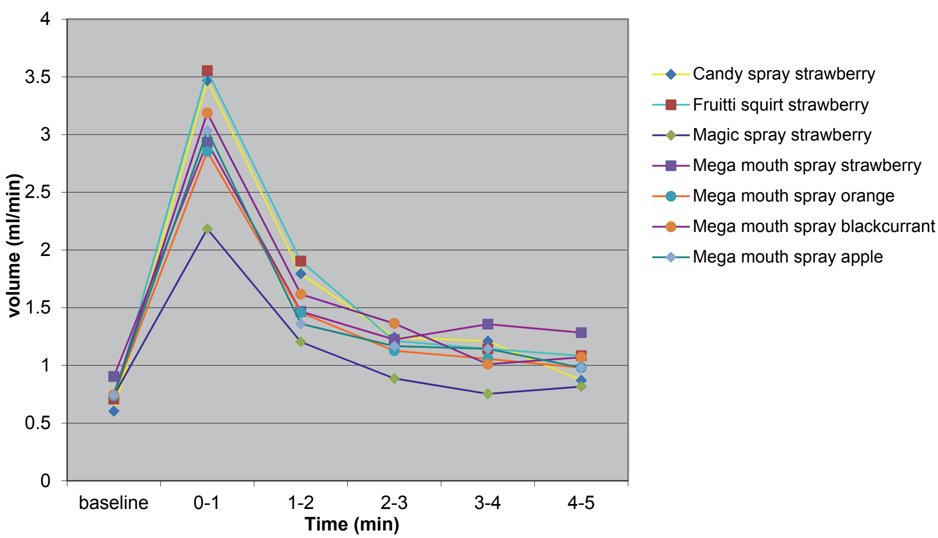

Figure 5. Mean salivary flow rate at different time points after application of seven different candy sprays (n =3).

and 5.8 (Figure 6). The strongest decrease in salivary pH was observed using the Candy spray strawberry (pH 4.4) and the Fruitti squirt strawberry (pH 4.8). For the Magic spray strawberry and the Mega mouth spray apple, the salivary pH remained above pH 5.5. Both the salivary flow rate and the pH returned to the initial values within 2-3 minutes (Figures 5 and 6).

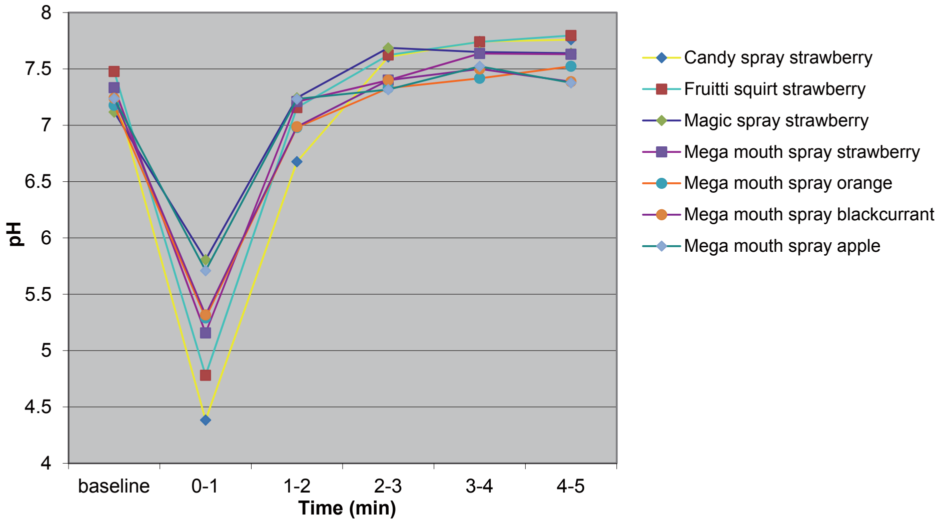

Figure 6. Mean pH of saliva at different time points after application of seven different candy sprays (n =3).

DISCUSSION

The aim of this study was to compare the potential erosive effects of several candy sprays. All candy sprays tested were highly acidic, indicating that they contain high levels of citric acid (Table 1). Their initial pH values ranged from 1.90 – 2.28, well below the pH-value of 5.5 that has generally been adopted as the critical value below which hydroxyapatite may dissolve (Ericsson, 1949; Larsen and Pearce, 2003).

The erosive potential of candy sprays is determined by the pH, the titratable amount of acid and the volume administered. The greater the titratable acidity of the candy spray, the longer it will take for saliva to neutralize it (Lussi *et al.*, 2004). Of the candy sprays tested, the Candy spray strawberry and the Fruitti squirt strawberry have the highest titratable acidity (Figure 4). After intraoral administration of these two candy sprays, pH values of saliva dropped far below 5.5 (Figure 6), indicating that this type of candy has the potential to lower the salivary pH *in vivo* considerably. This is in agreement with studies showing the erosive potential of solid acidic candies (Davies *et al.*, 2008; Jensdottir *et al.*, 2005 and 2007; Bibby and Mundorff, 1975; Lussi *et al.*, 1997). Administration of the Magic spray strawberry induced the smallest decrease in salivary pH. This is probably related to three factors. First, this candy spray has a higher pH

(Table 1). Second, the amount of titratable acidity in Magic spray strawberry is smaller (Figure 4). Third, the volume of a single dose of this candy spray is considerably smaller than the other candy sprays tested (Table 1 and Figure 4).

Candy sprays stimulate the salivary flow immediately after they have been introduced into the mouth (Figure 5). The buffering and diluting effects of the stimulated salivary flow may provide some protection against the erosive potential of acidic candy (Davies *et al.*, 2008; Jensdottir *et al.*, 2005; Hunter *et al.*, 2008). However, citric acid is a complex organic acid. At low pH values, citric acid provides protons which directly attack the mineral surface. At higher pH levels, around pH 7.0, the citrate anion may draw calcium away from the enamel by chelation. This means that the demineralising effect of citric acid is exceptionally great and may even continue after the pH at the tooth surface has increased (Järvinen *et al.*, 1990; Hunter *et al.*, 2008; Lussi and Jaeggi, 2008).

Our *in vivo* results are based on a single administration of candy spray to adult volunteers. However, candy sprays are frequently used by children during the day (Gambon *et al.*, 2006) and the volume of saliva in children is smaller than in adults (Crossner, 1984; Watanabe and Dawes, 1990). Therefore, in children a single dose of a candy spray will introduce a relatively higher amount of candy spray in the oral cavity and thus probably result in an even lower salivary pH value. Repeated use of candy sprays may also exacerbate the erosive potential, as the longer the teeth are bathed in acid the longer the period of time for erosion to occur and the less time for remineralisation (Lussi *et al.*, 2004; Moynihan, 2002).

The susceptibility of deciduous and permanent enamel to erosion by the consumption of solid candy and acidic drinks with a low pH is different. The deciduous teeth are smaller, the enamel is thinner and softer and in combination with a continuously increasing acidic intake the demineralisation is more prone (Davies *et al.*, 2008; Hunter *et al.*, 2000a and 2000b).

CONCLUSION

In summary, candy sprays are potentially capable to cause dental erosion. Both health-care professionals as well as consumers should be aware of this erosive potential. However, candy sprays are usually consumed by young children. In 70% of the cases, their parents were unaware that their children used this type of candy (Gambon *et al.*, 2006). Therefore, both juvenile patients and their parents should be informed that (excessive) use of candy sprays may cause dental erosion.

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Chapter 8

Straw use in young children and the potential relation to tooth wear

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Submitted for publication

ABSTRACT

Objective: To collect information about the use of drinking straws by young children and the possible relation of biting on these straws to tooth wear.
Design: single centre, cross-sectional study.
Setting: paediatric dental practice.
Methods: Straws were collected after being used by children (n=421, 4-6-years-old) and classified as undamaged, damaged without deformation or damaged with deformation. Subsequently, the primary maxillary incisors of 69 other children (4-7 years) were photographed, and scored by two dentists with regard to tooth wear. The parents of these children provided information about consumption pattern and use of straws.
Results: After use, only 11% of the straws were undamaged, 60% were damaged and 29% damaged with deformation. The 4-year-old children had the highest percentage of damaged and deformed straws. Of the second group of children, more than 80% were classified as having tooth wear or dental erosion. The presence of tooth wear and dental erosion incisally on the upper incisors were both related to the habit of damaging straws during beverage consumption.
Conclusion: Many young children chew on their drinking straws while using them. When tooth wear of the primary maxillary incisors is observed in children, the (incorrect) use of straws should be discussed with their parents.

INTRODUCTION

Different processes are responsible for tooth wear: abrasion (wear produced by interaction between teeth and other materials), attrition (loss of tooth tissue as a consequence of tooth-tooth contact) and erosion (dissolution of hard tissue by acidic substances without the involvement of bacteria) (ten Cate and Imfeld, 1996). It is well-recognized that these different mechanisms interact with each other resulting in clinically observed patterns of the loss of dental hard tissue (Eisenburger and Addy, 2002; Davis and Winter, 1980; Amaechi *et al*., 2003; Mair, 2000; Barlett and Smith, 2000; Meurman and Sovari, 2000).

Consumption of acidic beverages is considered to be a major factor in the etiology of dental erosion. Acidic drinks contain phosphoric, citric or other acids, often resulting in a pH less than 4.0, far below the critical value for hydroxyapatite decalcification (Järvinen *et al*., 1990; Lussi *et al*., 2004; Moynihan, 2002).

To prevent development of dental erosion, the frequency and the severity of contact with acidic beverages should be reduced (Imfeld, 1996; Lussi and Hellwig, 2006). Dental erosion in enamel that is exposed to a flowing acidic solution, is dependent on the total volume of solution, the exposure time as well as the flow rate of the liquid (Eisenburger and Addy, 2003; Shellis *et al*., 2005). Therefore, several authors advise to consume acidic beverages with a drinking straw positioned towards the back of the oral cavity. This will reduce the contact time between the teeth and the acidic drink, and tends to direct liquid away from the anterior teeth thus reducing its erosive action (Moynihan, 2002; Eccles and Jenkins, 1974; Grobler *et al*., 1985; Edwards *et al*., 1998). However, case reports have been published that a straw placed labial to the anterior teeth may result in rapid development of erosion (Shellis *et al*., 2005; Mackie and Hobson, 1986; Mackie and Blinkhorn, 1989).

In a paediatric dental clinic, we observed some children with a remarkable pattern of abrasion and dental erosion on the primary maxillary incisors (Figure 1). Most of them were biting on the straw while drinking (Figure 2). This biting could change the opening of the straw,

Figure 1. Dental erosion of the upper primary incisors.

Figure 2. Deformation of the straw between the teeth and tissue loss of the primary incisors.

potentially resulting in an increased velocity of the liquid and a subsequent higher risk of dental erosion (Eisenburger and Addy, 2003; Shellis *et al*., 2005).

The aim of the study was twofold. First to establish the frequency with which young children bite on straws during drinking. Second to explore the potential relation between this straw biting habit and dental tissue loss.

MATERIAL AND METHODS

The inventory study was performed in September and October 2009. During this time, six different primary schools were visited in Rotterdam, the Netherlands. At each school, drinking straws were collected from children of 4- to 6-years-old. The straws were collected immediately after the children had used it to drink from a small carton box during their lunchtime. Each straw was coded, and age and gender of the children were registered. The type of beverage consumed was not recorded.

In the first part of the study a total of 421 straws from 421 different children were collected. Using typical examples (Figure 3), two observers (D.L.G. and L.R.) independently classified the straws as undamaged, damaged without deformation ('damaged') or damaged with deformation ('deformed'). The Kappa score of the classification by the two observers was very high (Kappa = 0.85). Afterwards, the two observers held a consensus meeting to classify the straws on which they initially did not agree.

In the second part of the study, the potential relation between straw deformation and tooth wear was explored in a paediatric dental clinic. After obtaining consent from their parents, 81 other children between 4 and 7 years were invited to participate. Twelve children were excluded (three for extensive caries and nine for missing primary maxillary incisors), resulting in a study population of 69 children. Standardised intraoral photographs were taken from the primary maxillary dentition. The parents were questioned whether their children usually bite on drinking straws during consumption of drinks.

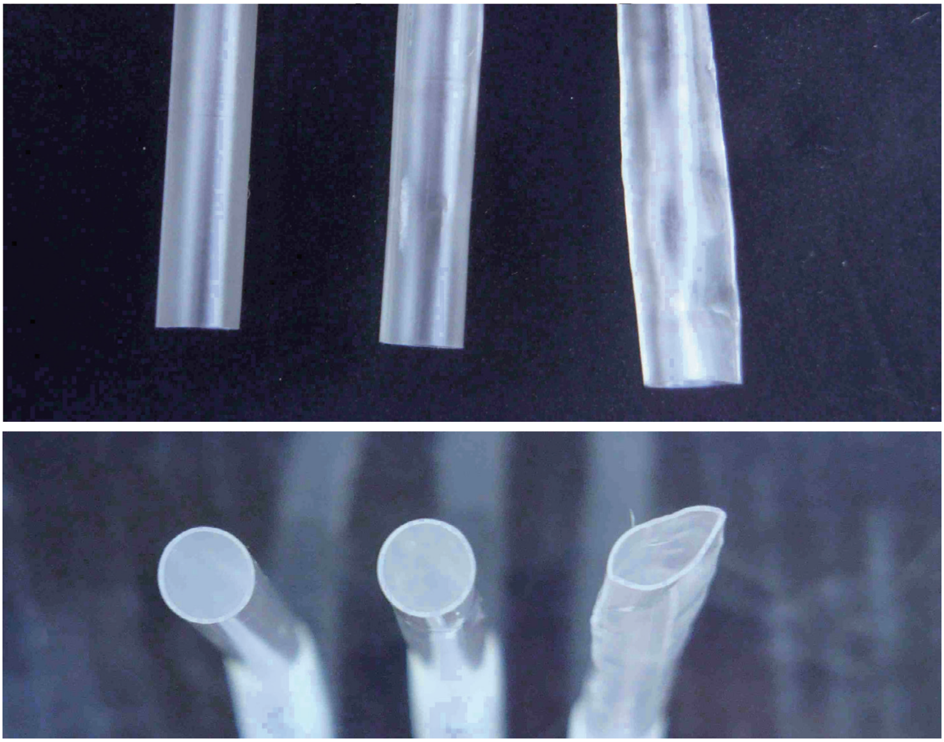

Figure 3. Different types of damaged straws: undamaged, damaged without deformation and damaged with deformation (from left to right).

The photographs were studied with regard to dental tissue loss by two dentists (D.L.G. and C.P.B.) independently from each other. When tooth wear was present, dental erosion was assessed using the clinical indices suggested by Lussi (Lussi, 1996). Afterwards, the two dentists held a consensus meeting to classify the photographs on which they initially did not agree.

STATISTICS

All data were analyzed with Chi-square tests using the statistical software package SPSS version 15.0.1 (SPSS Inc., Chicago, IL, USA). The intraobserver agreement was assessed using Cohen's Kappa statistics. Significance was accepted at the $p < 0.05$ level.

RESULTS

A total number of 421 straws from different children were collected. Only 11% of the straws were undamaged after they were used to consume a drink, 60% were classified as damaged

Table 1. Condition of straws after primary school children used it to drink one small carton box. The condition of the straw was classified as undamaged, damaged or deformed. Data are presented as percentages, and stratified according to age and gender of the children.

	Undamaged	Damaged	Deformed
Total (n=421)	11%	60%	29%
Age			
4 yr (n=145)	8%	59%	34%
5 yr (n=128)	9%	55%	35%
6 yr (n=148)#	17%	65%	18%
Gender			
Boys (=214)	12%	57%	31%
Girls (n=207)	11%	62%	27%

Chi-square significant different versus 4-yr (p=0.002) and 5-yr (p=0.003)

and 29% showed damage in combination with deformation (Table 1). The type of damage was related to the age of the children. The highest level of undamaged straws was observed for 6-year-old children. Gender was not significantly related to damage or deformation of the straws (Chi-square p=0.574). Statistical differences in type of damage were observed between the six participating primary schools, with percentages undamaged straws varying from 5 to 25% and the deformed straws ranging from 15 to 38% (Chi-square $p < 0.0005$).

Intraoral photographs were taken from the primary front teeth of 69 other children, 34 boys and 35 girls. The intraobserver agreement with regard to dental tissue loss was high (Kappa=0.70). Eighty-seven percent of the children showed signs of tooth wear, 83% had dental erosion on the incisal surfaces of the maxillary primary incisors. There was no significant difference between boys and girls in tooth wear (p=0.756) and dental erosion (p=0.517). According to their parents, 45% of this second group of children used a straw to consume milk, 45% for fruit juices and 57% for lemonade. No statistical significant relation was observed between type of beverage consumed and the presence of tooth wear. According to their parents, 75% of the children was biting on drinking straws. This reported biting on straws was highly significantly associated with tooth wear in general and dental erosion incisally ($p<0.0005$).

DISCUSSION

This inventory study shows that the majority of young children damages or deforms their drinking straw during consumption. The highest levels of undamaged straws were observed for 6-year-old children, significantly higher than in children of 4- and 5- years-old (Table 1). The age-related increase in undamaged straws may be related by Freud's theory of child development. During the first two years of life a child is focused on oral pleasures, such as sucking and biting on objects. This oral fixation gradually decreases when growing up (Freud, 1969). Deformation of straws during consumption was not related to gender (Table 1). This observation is in line with a previous study that the occlusal force showed no significant gender difference for children at 7-years-old (Maki *et al*., 2001).

Several authors have suggested the use of straws would prevent dental erosion (Imfeld, 1996; Eccles and Jenkins, 1974; Grobler *et al*., 1985; Edwards *et al*., 1998). However, our results suggest that biting on a straw may increase the risk of tooth wear. Biting could have changed the opening of the straw, resulting in an increased flow of the liquid against the dental enamel. Previous studies have shown that erosion of dental enamel is dependent on the liquid's velocity (Eisenburger and Addy, 2003; Shellis *et al*., 2005). This effect could be more pronounced in deciduous enamel which is softer than permanent enamel and more susceptible to demineralisation (Amaechi *et al*., 1999; Attin *et al*., 1997; Anderson *et al*., 2001; Johansson *et al*., 2001; Lippert *et al*., 2004). The exposure of enamel to acid may also render it more vulnerable to abrasion by the chewing on the drinking straw (Addy and Shellis, 2006).

The observation that biting on a straw is associated with an increased risk of tooth wear suggests that the children do not position the tip of the straw at the advised location. Positioning towards the back of the oral cavity likely will prevent that an increased liquid flow from the tip of the straw will affect the enamel of the maxillary incisors.

This initial study on the possible relation between the habit of children to damage straws and the development of tooth wear has several limitations. In the first place it is a cross-sectional study performed in one city (Rotterdam) that may not be representative for the entire country. Secondly, the dentists used photographs to determine the presence of tooth wear, and their opinion could potentially have been influenced after a full clinical examination of the dentition. Finally, in the second part of the study, the data on beverage consumption and biting on straws were provided by the parents. This information may have been influenced by recall-bias or social desirable responses. Also, the parents did not provide information on the number of consumptions, just on the type of consumptions.

Therefore, further larger prospective studies are needed. These studies should also include the type of beverages consumed and the socioeconomic status of the children, factors that influence the prevalence of dental erosion in children (Lussi *et al.*, 2004 and 2000; Millward *et al*., 1994a and 1994b). E.g. differences in socioeconomic status could have contributed to the observed differences in the condition of the straws between the participating schools. It is important that dentists provide information on the use of drinking straws to young children, their parents and teachers. When tooth wear of the primary maxillary incisors is observed in children, the (incorrect) use of straws should be discussed with their parents.

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Chapter 9

General discussion, conclusion and recommendations

General discussion

Dental erosion in the 21st century: What is happening in society with nutritional habits and lifestyle?

As early as 1908 G.V. Black estimated that the prevalence of dental erosion was less than 0.1%. He hypothesized that the origin might be hereditary, but also listed other possible etiologies from developmental, systemic, or extrinsic origin (Black, 1908). In the last 20 years, epidemiological studies have been published showing that nowadays a high percentage of young people show signs of dental erosion (Bartlett *et al*., 1998; Milosevic *et al*., 1994). The prevalence of erosive tooth wear is still increasing, especially in the younger age groups (Al-Dlaigan *et al*., 2001; Dugmore and Rock, 2004a; Nunn *et al*., 2003; Truin *et al*., 2005; El Aidi *et al*., 2010). The main explanation for this phenomenon is a change in nutritional habits and lifestyle (Calvadini *et al*., 2000; O'Sullivan and Curzon, 2000; Lussi and Schaffner, 2000).

Working as a dentist in a paediatric dental clinic in a major city since 1995, I diagnosed erosive tooth wear in different kinds of stages in many children between 3 and 18 years old. In these children, I had to identify the possible cause of the erosive tooth wear. Clinically it can be difficult to determine the major cause of tooth wear in a patient, although the appearance and the location of the tooth wear may be helpful (O'Sullivan and Milosevic, 2008). These clinical problems ignited a sense of curiosity in me about the potential etiological factors in erosive tooth wear, which was the starting point for the research described in this thesis.

Starting with a 9-year-old boy with severe tooth wear, insight was obtained about deviant behaviour contributing to the development of dental erosion. This boy developed severe dental erosion due to the consumption of a single glass of soft drink per day while he was gaming intensively on his computer (Chapter 1). Today many children and adolescents spend several hours per day behind a game console or computer. Some of these kids consume small amounts of (acidic) foods and/or sipping soft drinks, while gaming over a long period of time. Parafunctional habits, like clenching during an exciting game, can potentiate the clinical tooth wear induced by relatively small volumes of soft drinks. Indeed a recent *in vitro* study showed that eroded human enamel is more vulnerable to mechanical stress (Heurich *et al.*, 2010).

Probably, hardly any of these children and/or their parents will be aware of this synergistic risk on tooth wear. Therefore it is useful for dentists to counsel juvenile patients with tooth wear not only about the erosive potential of soft drinks, but also about the way they are consumed.

Taste preference

In earlier times, nearly all newborns were breastfed. They got accustomed to the sweet taste of breast milk and toddlers learned to dislike sour tasting foods and drinks. In 1887 Charles Darwin already observed that the sensory world of children differs from that of adults. He noted the strong acceptance of sweet tasting sugars during infancy and childhood, with preference levels decreasing into adult life (Darwin, 1887). A century later, scientific research of taste preferences during human ontogeny has confirmed Darwin's assumptions (Desor *et al.*, 1975; Enns et al., 1979; Maller and Desor, 1973; Nisbett and Gurwitz, 1970; Peiper, 1963; Steiner, 1977; Desor and Beauchamp, 1987). The enhanced preference for sweet taste during early development is universal and evident in children all over the world (De Graaf and Zandstra, 1999; Beauchamp and Cowart, 1987; Jamel *et al.*, 1997), although individual differences do exist (Beauchamp and Moran, 1984; Enns et al., 1979), based on genetic variation (Bartoshuk, 2000) or early experience (Beauchamp and Moran, 1982 and 1984).

Taste receptors can be grouped into five basic tastes: sweet, sour, salt, bitter and umami. Taste preference has a strong innate component. Sweet and salty substances are innately preferred, whereas bitter and many sour substances are innately rejected (preferences for umami have hardly been studied). Despite the innate component, taste preferences can be modified and adapted.

Through dietary experiences, children will learn which types of food have a sweet taste or not (Cowart and Beauchamp, 1986; Sullivan and Birch, 1990). Previous experiences with flavours influence subsequent flavour preferences in the same way, even years after the initial experience. Especially early experiences with sweet and sour taste can influence flavour preferences during childhood. Preferences for sour taste are related to exposure to sour food during infancy and cannot easily be changed by short repeated exposure during childhood. This is in contrast with preference for sweet taste, which can be increased by a short repeated exposure during childhood (Liem and Mennella, 2002).

Experiments studying the most preferred level of sourness of gelatin showed that sour preferences increase during childhood and that these preferences are related to children's food habits and preferences. Children who preferred extreme sour tastes are not only more likely to try extreme sour foods but they continue to eat such foods and subsequently develop a preference for extremely sour flavours. For example they are more likely to try extreme sour candy (Liem and Mennella, 2003). Another study examining the relationships between acceptance of extreme sour taste and fruit intakes in 18-months-old infants confirms previous outcomes that early experiences may influence sour flavour acceptance. The results suggest a relationship between infants' increased intake of fruits and the acceptance of sour tastes (Blossfeld *et al*., 2007). Comparing the intake of fruits at an age of 8 to 11 years and the preferred balance between sweet and sour taste showed that boys have a preference for higher concentrations of citric acid than girls, which correlated with a higher fruit intake (Liem *et al*., 2006). Initially mixing grapefruit juice with sucrose increased preference for the sour taste of grapefruit juice (without the added sucrose) and this persisted for several weeks thereafter (Capaldi and Privetera, 2008).

A large study among 8900 children and young people demonstrated that girls are better able to recognize tastes than boys. Between childhood and teenage years the ability to recognize tastes increases gradually, with the greatest change observed around the age of 13 to 14 years. At this age, children become much more sensitive to sour tastes and the taste for very sweet food and drinks begins to fade. Girls generally prefer flavours which are not too strong.

Boys, on the other hand, tend to like the more extreme flavours, giving top marks to the sourest samples, and most preferred the super-sweet soft drink. The children who prefer sour flavours are also more open to taste new foods (Allesen-Holm *et al.*, 2008).

Taken together, these studies on changes in taste perception indicate an age-related increased preference for sour foods and drinks, which may play a role in the development of dental erosion.

Consumption in adolescence related to childhood intake

Consumption patterns and preferences for food and beverages begin to develop in early childhood, and can influence preferences and nutrient intake at later phases in life (Skinner *et al*., 2002). As taste preference is related to the consumption of acidic foods, this can be an important factor in the development of dental erosion.

Soft drinks consumption at a young age predicts the pattern of nutrient intake during childhood and in adolescence. A study on the intake of soda containing beverages by girls showed that those who were consuming soda beverages at age of 5 years had a higher soda intake and a lower milk intake between the ages of 5 to 15 years (Fiorito *et al*., 2010). Another study also found that the intake of soft drinks in adolescence is significantly related to the intake level of soft drinks in early childhood as well (Kvaavik *et al*., 2005). A group of adolescents reporting the most frequent consumption of soft drinks at age 14 still reported the most frequent consumption at age 21. At both ages, males showed a higher intake of soft drinks than females (Lien *et al*., 2001).

Dental erosion in boys and girls

Loss of dental tissue is more frequently observed in males than in females (Al-Dlaigan *et al.*, 2001; Dugmore and Rock, 2004 and 2003). Progression of tooth loss develops more rapidly in boys than in girls (El Aidi *et al*., 2010). Consumption of soft drinks is more popular among boys and they have a higher average intake than girls (El Aidi *et al.*, 2008; van Rijkom *et al.*, 2002). Boys also drink more sports drinks and energy drinks (Al-Dlaigan *et al*., 2001; Grimm *et al*., 2004), which was confirmed in our study about patterns of consumption of potentially erosive beverages among adolescent school children in the Netherlands (Chapter 3). Boys consumed more frequently soft drinks, energy drinks and sports drinks than girls, and on average also consumed higher quantities of each of these drinks. The significant positive associations between the consumed amount of soft drinks, energy drinks and sports drinks in our study indicate that a subgroup of school children (14 or 15 years of age) has a high intake of soft drinks combined with high amounts of other types of acidic beverages. Consequently, the teeth of these children are very frequently exposed to acids, and consequently are at risk for developing dental erosion.

Level of prosperity and consumption pattern

In the early twentieth century, the availability of vegetables and fruits was dependent on season, and choices were limited to regional products. With the increased level of prosperity in the Western world, more food and drinks became available. Especially since the Second World War, the supply of fruit and vegetables changed dramatically. Products that were once seasonal products in Western Europe, like tomatoes, citrus fruits, limes, grapes, strawberries, raspberries and pineapples are available nowadays the whole year. In addition, new exotic types of acidic fruits were introduced, such as kiwis and pomegranates.

During the same era, the availability of candy has increased dramatically. Many new types and tastes of candies were developed. The caries risk of sugar containing candy became well known. However, many hard candies contain organic acid, such as citric acid, malic acid and/or fumaric acid, for a fresh taste. These organic acids are potentially erosive for the dental enamel as they can induce a drop in salivary pH to values below 5.5 so that erosion of teeth can occur (Davies *et al*., 2008; Jensdottir *et al*., 2005; Lussi *et al*., 1997; Gambon *et al*., 2006; Brand *et al*., 2009).

Erosive potential of hard candies

The erosive potential of several types of candy was explored in chapter 4 to 7. These studies investigated the influence of different kinds of candies such as candy sprays, lollipops, jawbreakers, winegums, gumballs, strawberry stripes and fruitgums on the flow rate, buffer capacity and pH of saliva. All candies increased the salivary flow rate greatly. Despite this increased secretion of saliva, several types of candy induced a dramatical drop in salivary pH to values below pH 4 or even lower. When the candies were removed from the mouth, both the pH and the secretion rate of saliva normalized rapidly.

When consumption is limited to a single piece of candy (or a single dose of candy spray), the effect of the decrease in salivary pH on the dental enamel will be minimal. However, many children and adults consume acidified candies frequently. In addition, some types of hard candy are kept in the mouth for a long time. The use of lollipops, especially the fruit-flavoured and cola-flavoured lollipops may have a pronounced erosive potential. The teeth are exposed to an acidic milieu for a long period of time, and the time for remineralisation will be short (Lussi *et al*., 2004; Moynihan, 2002). It has to be noted that addition of calcium to lollipops will lower the critical pH value at which dissolution of hydroxyapatite occurs (Dawes, 2003). Similarly, addition of calcium to erosive lozenges and drinks decreased the critical pH below which hydroxyapatite dissolved in acid (Jensdottir *et al*., 2007; Dawes, 2003) and reduced the enamel softening induced by sports drinks and juices with a low pH (Lussi and Jaeggi, 2008).

Frequent use of candies and sprays will increase the risk of enamel demineralisation. Most of the *in vivo* results were based on a single administration of candy or candy spray to adult volunteers. Candy sprays and other types of candies are more frequently used by children (Gambon *et al*., 2006) and the intraoral volume of saliva in children is smaller (Crossner, 1984; Watanabe and Dawes, 1990). Therefore, a single piece of acidified candy or a single dose of candy spray will result in an even lower salivary pH value in children. The repeated use of candies and spray may also exacerbate the erosive potential, since the longer the teeth are bathed in an acidic solution there will be a longer time for demineralisation and a shorter time for remineralisation (Lussi *et al*., 2004; Moynihan, 2002).

The mineral content of enamel from deciduous teeth is lower than in permanent teeth. Several *in vitro* studies suggest that deciduous teeth and permanent teeth are equally susceptible to erosion (Lussi *et al.,* 2000; Johansson *et al*., 2001). However, enamel of deciduous teeth seems more susceptible than permanent teeth with an increased frequency of acidic consumption of four times a day (Hunter *et al.*, 2000a and 2000b). Therefore, it is recommendable that consumption of acidic candy by children is limited as much as possible. The risk of dental erosion can be further reduced by keeping the candy in the mouth as short as possible and rinsing the oral cavity with water immediately after consumption. In addition, the risk of developing dental erosion could be further reduced by application of a fluoride-containing varnish (Vieira *et al.*, 2007).

Acidic drinks and use of straws

As lifestyle has changed through the last decades, the total amount and frequency of consumption of acidic drinks and foods has changed too. In the past, most people consumed all their food and drinks only during meals. Today young people eat and drink more frequently and/or in larger quantities (French *et al.,* 2003). In addition, new types of packaging of foods and drinks make it possible to reseal bottles and packages, resulting in frequent exposure to small amounts of acidic consumptions. In the Netherlands, resealable mugs are more and more replaced by pre-packed small carton boxes, provided with a drinking straw. Especially parents find this a comfortable way to give their child a drink to school, as the carton boxes prevent leakage of fluids which sometimes occurs with the resealable mugs. It is evident that children and adults, sipping regularly during the whole day from bottles with low pH-drinks and/or having little bites from erosive snacks over a longer period, have a high risk for dental erosion.

What about the role of drinking straws in relation to tooth wear? Several authors advise to consume acidic beverages with a drinking straw positioned towards the back of the oral cavity to prevent dental erosion (Imfeld, 1996; Eccles and Jenkins, 1974; Grobler *et al*., 1985; Edwards *et al*., 1998). However, some authors described patients placing a straw labial to the anterior teeth who developed erosion rapidly (Shellis *et al*., 2005; Mackie and Hobson, 1986; Mackie and Blinkhorn, 1989). In our studies, we observed that use of drinking straw and biting on it are related with an increased risk of tooth wear (Chapter 8). This suggests that many children do not use drinking straws correctly and/or do not position the tip of the straw at the advised location. Therefore, when tooth wear of the primary maxillary incisors is observed in children, dentists should discuss the (incorrect) way the drinking straw is used with the children and their parents.

School canteens

The increased level of prosperity not only increased the supply and choice of foods and drinks in stores and at home, but affected also the amount and type of products available at schools. In the Netherlands, children at secondary schools are able to buy and consume foods and soft drinks during the whole day. Many of the products available at Dutch school canteens are potentially erosive (Chapter 2). Significant correlations were observed between the number of different erosive drinks available at school canteens and the number of different products, the number of students, the opening hours of the canteens and the number of vending machines in the school. On the other hand, the available erosive food and beverages were not related to the school type, educational level and location of the school.The sale of these potentially erosive food products during school hours may contribute to the development of dental erosion in children.

Consumption of soft drinks is a contributing factor to several health problems, such as overweight, obesity (Ludwig *et al.*, 2001; James and Kerr, 2005), diabetes (Botero and Wolfsdorf, 2005) and dental problems (Tahmassebi *et al*., 2006; Lee and Messer, 2010). Schools are in a unique position to improve dietary behaviours of juveniles and thereby prevent future health problems in general. In some countries sugar-containing beverages have been banned from schools and were replaced by sugar-free alternatives and non-artificially sweetened fruit juices. Although this may have a positive effect on the development of caries and obesity, it seems doubtful whether this will affect the incidence of dental erosion. Sugar-containing beverages and non-sugar-containing variants do not differ significantly in erosive potential *in vitro* (Lussi and Jaeggi, 2006). However, other studies suggest that diet cola beverages were less erosive than regular cola drinks (Owens *et al.*, 2007; Rytömaa *et al.*, 1988).

In a recent Dutch study the feasibility and effectiveness of placing water coolers on the sales of sugar-sweetened beverages at secondary schools was investigated. Placement of water coolers appeared to be a feasible intervention at schools, but this did not affect the sales of sugar-sweetened beverages in the school canteens (Visscher *et al.*, 2010). A change in eating and drinking behaviour of children remains a real challenge. Regulations on the availability of unhealthy and erosive products in schools seem to be necessary. Restriction of the opening hours of school canteens and a ban on vending machines are other possible options in the struggle for healthy teeth and a healthy body of adolescents.

Influence of marketing

The increased level of prosperity, taste changes and availability of erosive food products in stores and school canteens are not the only reasons responsible for the increased consumption of soft drinks and acidic candies, and the presence of dental erosion. New food stuffs and soft drinks are marketed aggressively, and undoubtedly this marketing is an important factor in children's consumption of unhealthy and erosive food. Food companies market directly to children, bypassing parents, in a myriad of ways.

Food advertisement on television is effective, especially when products are brand licensed with characters that children know well from television. Product placement in children's television programs and junk-food promotion by movie tie-ins is also well known. Advergaming is the practice of using video games to advertise a product. These computer games are completely developed around the product to be promoted and keep children's attention focused on specific brands much longer than traditional commercials. Even infants and toddlers are not exempt from food marketing. Product placement can be found in children's books including those for babies. Food companies also market to children with toys. Together, these advertisements influence children's intake of food and beverages very effectively (Linn and Golin, 2006). In addition, in supermarkets it is common practice to place sweets just before the cashier. Placed at eye-height of children, many tempted children will try to persuade their parents to buy these products, while queuing for paying.

Toothfriendly logo

More knowledge among children and parents about erosive foods and beverages may decrease the risk on dental erosion. The non-profit association Toothfriendly was established in 1989. This organization has developed the Toothfriendly logo, a registered trademark, which labels confectionery products that are really toothfriendly, i.e. non-cariogenic and non-erosive. Manufacturers who wish to use the Toothfriendly logo on their product and in advertisements must have tested their product(s) for 'toothfriendliness' at accredited test centres. Until now, only a very few of Toothfriendly labeled products have appeared on the market. Many children and parents are unaware of the meaning of the Toothfriendly logo and its importance in the Netherlands is almost unknown. Therefore, more knowledge is required and more products should be developed that are really toothfriendly!

Development of new, less erosive products

Addition of calcium, phosphate and/or fluoride to erosive drinks and lozenges decreases the critical pH below which hydroxyapatite dissolves in acid (Jensdottir *et al*., 2007; Dawes, 2003; Larsen and Nyvad,1999; Hughes *et al*., 1999) and reduces the enamel softening effects of low pH sports drinks and juices (Lussi and Jaeggi, 2008; Venables *et al*., 2005). Unfortunately, addition of calcium can influence the taste giving a drink a more bitter taste. Other new drinks have been developed containing smaller amounts of acid, but the subjects testing these drinks no longer considered the taste as fresh.

In the United Kingdom the first commercially available fruit drink with reduced erosive potential was 'Ribena'. This drink is fruit based, making it more acceptable with regard to taste. In the Netherlands, 'Joy' was brought on the market in 2004. This newly developed drink, also fruit based, was available in three different flavours. The new soft drink induced statistically significantly less erosion depth when compared with cola and apple juice but this was not statistically different from orange soda (Huysmans *et al*., 2006). Today, this drink has already disappeared from the market because the children did not like its taste.

Manufacturers of fruit drinks and juices are looking for other solutions, but even the so-called 'less sour fruit drinks' have pH values below 5.5. Development of new products with a less erosive potential has been recommended, but companies mainly seem to invest in marketing. Since profits of the current erosive foods and beverages are high, companies do not really need to develop healthier products with the risk of a commercial failure. However, new initiatives are needed and remain welcome.

CONCLUSION

A general conclusion from this thesis is that many factors in the 21st century can lead to dental erosion in (young) children and adolescents. Knowledge of the risk factors and protecting factors is a prerequisite for prevention of dental erosion. Therefore, the parents and children should receive comprehensive information about the risks of the intake of acid food and drinks, as well as recommendations about toothfriendly eating and drinking habits.

Recommendations to prevent erosive tooth wear in children

- Introduce acidic drinks as late as possible to young children;
- Let children become accustomed to water, tea or dairy products;
- Parents, teachers and health-care workers should inform children and adolescents about the risk of dental erosion;
- Parents must set an example for their children with limited consumption of acidic beverages;
- Drink non-erosive drinks such as (mineral)water, yogurt drink or natural tea;
- Ban soft drink vending machines from school canteens;
- Diminish the consumption frequency of acid-containing candy, food and drinks;
- Drink acidic beverages quickly without rinsing the oral cavity;
- Do not hold or swish the acidic drinks around the tongue;
- Do not drink slowly by nipping or sipping;
- Use a drinking straw placed towards the back of the oral cavity;
- After consumption of acidic food or drink, rinse the oral cavity with water.

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Summary

Chapter 1

Dental erosion is the loss of dental hard tissue that is chemically etched away from the tooth surface by acid without bacterial involvement. The prevalence of erosive tooth wear is still increasing, especially in the younger age groups. This has been attributed to changes in nutritional habits and lifestyle, which provided the basis for further research described in this thesis.

Today many children and adolescents spend a lot of time behind their computers. Some of them are eating small amounts of (acidic) food and/or drinking soft drinks with small sips, while gaming over a longer period of time. Therefore, they form a group at risk for erosive wear of their dentition. In combination with parafunctional habits, e.g. bruxism, this can lead to severe tooth wear.

This was illustrated by the case report of a 9-year-old boy. He consumed one single glass of soft drink while he was gaming intensively on his computer, and developed severe tooth wear at young age.

Chapter 2

Schools are in a unique position to improve the health status and dietary behaviour of children. School canteens provide children with a wide range of food choices, which may include risk factors for developing dental erosion. Therefore, we performed a cross-sectional study among 43 locations of 37 secondary schools in the Netherlands. This study showed that many different products are available in canteens of Dutch secondary schools, a high proportion of the drinks being potentially erosive (71.8±12.9%). The number of different products available, the number of different beverages available and the number of erosive drinks were all related to the number of students per school, but not to the type of education. The number of drinks available and the number of erosive drinks correlated with the opening hours of the canteens and the number of vending machines.

Consumption of the potentially erosive products during school hours may contribute to the development of dental erosion in school children. Restrictions on the canteen assortment, a reduction in opening hours of the canteen and/or a ban on vending machines could help to limit the exposure of Dutch school children to potentially erosive drinks.

Chapter 3

Several observational studies support an association between soft drink consumption and the incidence or severity of dental erosion. However, the observation that several other studies failed to demonstrate, a relationship between dental erosion and consumption of acidic beverages, indicates that focussing on a single type of drink may be too simplistic. Therefore, we explored the possible associations in consumption of various types of potentially erosive beverages among adolescent school children.

A cross-sectional single centre study was performed among 502 school children in Rotterdam, the Netherlands, in age varying between 12 and 19 years old. Boys consumed soft drinks, energy drinks and sports drinks more frequently than girls, and on average boys also consumed higher amounts of these drinks. No gender-related differences were observed in alcopop consumption. Consumption of all drinks was most frequent at 14 or 15 years of age, with the exception of alcopops which was most frequent by 16 years old school children. Significant positive associations were observed between the consumption of soft drinks, energy drink and/or sports drinks. Alcopop consumption was only associated with consumption of energy drinks.

Chapter 4-7

Different types of acidic candy may potentiate the risk on dental erosion. Therefore, the effects on salivary flow rate, buffer capacity and pH were studied of various types of candies, such as candy sprays, lollipops, jawbreakers, winegums, gumballs, strawberry stripes and fruitgum. All candies contained an organic acid, such as citric acid, malic acid and/or fumaric acid. Due to the presence of the organic acids, consumption of the candies increased the salivary flow rate greatly. Despite this increase in salivary flow rate, consumption of acidic candies induced a strong drop in salivary pH to values (far) below 5.5, the critical pH for dissolving dental enamel. The largest drop in salivary pH was observed during consumption of the candy sprays. However, the size of the hard candy may also play a role. The longest decrease in salivary pH was observed during consumption of fruit-flavoured and cola-flavoured lollipops. After removal of the candy from the mouth, both the pH and the salivary secretion rate normalized rapidly.

When consumption of acidic candies is limited to a single piece (or a single dose of candy spray), the length of the acidic attack is probably too short for permanent damage to the dental surface. During consumption of lollipops or jawbreakers, however, the teeth are much longer exposed to acid, resulting in a longer period of time for dissolution of dental mineral and a shorter time for remineralisation. Some lollipops contain extra calcium, which will decrease the critical pH value at which dissolution of hydroxyapatite occurs. As candy sprays and some other types of acidic candies are more frequently used by children and the volume of saliva in children is smaller than in adults, the erosive potential of these candies seems to be higher in children.

Chapter 8

To prevent development of dental erosion, the frequency and the severity of contact with acidic beverages should be reduced. Several authors advise to consume acidic beverages with a drinking straw positioned towards the back of the oral cavity. This will reduce the contact time between the teeth and the acidic drink, and tends to direct liquid away from the anterior teeth reducing its erosive action. However, several case reports have been published that a straw placed labial to the anterior teeth may result in rapid development of erosion of these frontal teeth.

In a paediatric dental clinic we observed some children with a remarkable pattern of abrasion and erosion of the primary maxillary incisors. Most of these children were biting on their straw while drinking. Therefore, we investigated the frequency with which young children bite on straws during drinking. Straws were collected after being used by children (n=421) between 4 and 6 years old and classified as undamaged, damaged without deformation or damaged with deformation. Only 11% of the straws were undamaged, 60% were damaged and 29% were damaged with deformation. The highest percentages of damaged and deformed straws were observed in 4-year-old children.

In a subsequent study, we explored the potential relation between this straw biting habit and dental tissue loss. The primary maxillary incisors of another group of 69 children (4 - 7 years) were photographed, and the photographs were scored by two dentists with regard to tooth wear. The parents of these children provided information about consumption pattern and the use of straws. Of this second group of children, more than 80% were classified as having tooth wear or dental erosion. The presence of tooth wear and dental erosion incisally on the upper incisors were both related to the habit of damaging straws during beverage consumption.

These preliminary studies show that many young children chew on their drinking straws while using them. When tooth wear of the primary maxillary incisors is observed in children, dental health care workers should discuss the possible (incorrect) use of straws with their parents.

Conclusion

A general conclusion from this thesis is that many factors in the 21st century can lead to dental erosion in (young) children and adolescents. Knowledge of the risk factors and protecting factors is a prerequisite for prevention of dental erosion. Therefore, the parents and children should receive comprehensive information about the risks of the intake of acid food and drinks, as well as recommendations about toothfriendly eating and drinking habits.

Tanderosie bij kinderen: risicofactoren in het dagelijks leven in de 21ste eeuw

SAMENVATTING

Hoofdstuk 1

Tanderosie wordt gedefinieerd als het oplossen van hard tandweefsel door inwerking van zuren die niet afkomstig zijn van bacteriën. Er zijn in de wetenschappelijke literatuur aanwijzingen dat de prevalentie van tanderosie nog steeds toeneemt, vooral bij jongeren. Veranderingen in eet- en drinkgewoonten en in levensstijl lijken hierbij een belangrijke rol te spelen. Met behulp van enquêtes en *in vivo* studies worden in dit proefschrift potentiële risico's voor het ontstaan van tanderosie onderzocht.

Tegenwoordig brengen veel kinderen en volwassenen lange tijd achter hun computer door, en vaak wordt ondertussen (zuur) voedsel en frisdrank geconsumeerd. Dit resulteert in demineralisatie (aantasting) van het tandglazuur, dat in combinatie met parafuncties, zoals bruxisme, kan leiden tot ernstig weefselverlies.

Dit wordt geïllustreerd door een casus van een negenjarig jongetje. Bij hem werd een ernstige vorm van tanderosie gediagnosticeerd als gevolg van een afwijkend drinkpatroon. Hij dronk elke dag gespreid over een lange periode één glas frisdrank, met kleine slokjes, terwijl hij zich zeer intensief bezig hield met computerspelletjes.

Hoofdstuk 2

Schoolkantines zijn in een unieke positie om de gezondheid en het eet- en drinkgedrag van kinderen te beïnvloeden. Ze bieden gewoonlijk een uitgebreid voedingsaanbod, maar het aandeel potentiële erosieve voedingsmiddelen daarin was onbekend. Door ons is onderzoek verricht naar het aanbod van voedingsmiddelen op 43 locaties van 37 verschillende middelbare scholen in Nederland. Alle aangeboden producten werden genoteerd en als potentieel erosief of niet- erosief geclassificeerd.

Van de verkochte dranken was 71.8±12.9% potentieel erosief. Het totaal aantal verschillende voedingsmiddelen, het aantal beschikbare dranken en het aantal potentieel erosieve dranken correleerden met de openingstijden van de kantines en het aantal aanwezige frisdrankautomaten. Consumptie van potentieel erosieve producten gedurende schooltijden kan bijdragen aan de ontwikkeling van tanderosie bij kinderen. Vermindering van het aanbod aan potentieel erosieve producten, beperking van de openingstijden van de kantines en het verwijderen van frisdrankautomaten uit de scholen kunnen bijdragen aan een vermindering van tanderosie.

Hoofdstuk 3

Verschillende studies rapporteren een relatie tussen de consumptie van frisdrank en de aanwezigheid en de ernst van tanderosie. Echter, het feit dat deze observatie in enkele andere onderzoeken niet bevestigd kon worden, suggereert dat een relatie tussen erosie en de consumptie van één soort drank wellicht een te simplistische benadering is. Wij hebben daarom onderzocht of de consumptie van verschillende soorten potentieel erosieve dranken door adolescenten onderling gerelateerd is.

Met vragenlijstonderzoek hebben we het consumptie gedrag van middelbare scholieren in de leeftijdsgroep van 12 tot 19 jaar in kaart gebracht. Daaruit blijkt dat jongens vaker en grotere hoeveelheden frisdrank, energiedrank en sportdrank drinken dan meisjes. Geen verschil tussen jongens en meisjes is gevonden in de consumptie van alcopops. Alle onderzochte dranken, met uitzondering van alcopops, werden het meest frequent door 14- en 15-jarigen gedronken. Alcopops werden het meest genuttigd door 16-jarigen. De consumptie van frisdrank, energiedrank en/of sportdranken bleek onderling positief gecorreleerd. Consumptie van alcopos was alleen gerelateerd met de consumptie van energiedranken.

Hoofdstuk 4-7

Aangezuurd snoep kan mogelijk bijdragen aan het ontstaan van tanderosie. Vandaar dat het effect op de secretiesnelheid, de buffercapaciteit en de pH van speeksel is onderzocht van verschillende soorten snoepgoed, zoals candy sprays, lollies, jawbreakers, fruittoffees, fruitgom, zure matten en winegums. Dit soort snoepproducten bevat een organisch zuur, zoals citroenzuur, appelzuur en/of fumaarzuur. Consumptie van aangezuurd snoep veroorzaakt een stijging van de speekselsecretie en een sterke daling van het speeksel pH tot waarden onder de 5.5. De sterkste daling van de speeksel pH werd waargenomen na gebruik van candy sprays. Consumptie van lollies met cola- of fruitsmaak geeft een langdurige daling in speeksel pH. Na afloop keren de secretiesnelheid en de pH van speeksel weer snel terug tot normaalwaarden.

Wanneer de consumptie van aangezuurd snoep beperkt blijft tot een enkel snoepje of een enkele dosis candy spray, is de duur van de zuuraanval waarschijnlijk te kort voor klinisch relevante schade aan het tandoppervlak. Bij consumptie van lollies of jawbreakers worden de gebitselementen echter gedurende lange tijd blootgesteld aan zuur, waardoor de demineralisatie toeneemt. Aan sommige van de onderzochte lollies is calcium toegevoegd. Dit leidt tot een verhoging van de calciumconcentratie in speeksel, wat tot gevolg heeft dat de pH-waarde waarbij demineralisatie van tandglazuur optreedt wordt verlaagd.

In ons onderzoek zijn de effecten van aangezuurd snoep onderzocht bij gezonde volwassenen. Sommige soorten aangezuurd snoep, zoals candy sprays, worden echter vooral door kinderen geconsumeerd. Aangezien het speekselvolume van kinderen kleiner is dan van volwassenen, is het aannemelijk dat de erosieve werking van deze soorten snoep bij kinderen groter is dan bij volwassenen.

Hoofdstuk 8

Om tanderosie te voorkomen is het belangrijk de frequentie en de contacttijd van zuur met de gebitselementen te beperken. Daarnaast is de mate van erosie door een zure vloeistof afhankelijk van het totale volume en de snelheid waarmee de vloeistof langs de gebitselementen gaat. Vandaar dat sommige wetenschappers het advies geven zure dranken te consumeren met een rietje, ver achter in de mondholte geplaatst, om zo de blootstelling van het gebit aan de zure drank te beperken. Echter, in casuïstiek wordt ook melding gemaakt van gebitsschade die veroorzaakt wordt door rietjes die labiaal zijn geplaatst.

In een kindertandartspraktijk werden enkele kinderen gediagnosticeerd met een opmerkelijk erosie- en abrasiepatroon bij de boven melkincisieven. De meeste van deze kinderen bleken tijdens het drinken uit een pakje op het rietje te bijten. Daarom hebben wij in het eerste deel van het onderzoek onderzocht hoe vaak jonge kinderen tijdens het drinken op een rietje bijten. Rietjes werden bij 421 kinderen (4 - 6 jaar) direct na gebruik verzameld en door twee onafhankelijke beoordelaars geclassificeerd als onbeschadigd, beschadigd of beschadigd met blijvende vervorming. Na gebruik bleek 11% van de rietjes onbeschadigd, 60% beschadigd en 29% had een blijvende vervorming. Bij vierjarigen werden vervormde rietjes het meest frequent waargenomen.

In het tweede deel van het onderzoek is de relatie onderzocht tussen bijten op het rietje en het voorkomen van gebitsschade. Daarvoor zijn de boven melkincisieven van 69 kinderen in de leeftijd van 4 tot 7 jaar gefotografeerd. Deze foto's zijn door twee tandartsen, onafhankelijk van elkaar, beoordeeld op gebitsslijtage. Informatie over het rietjesgebruik van de kinderen en de producten die de kinderen dronken werd verkregen van de ouders. Van deze tweede groep kinderen had meer dan 80% gebitsslijtage of erosie. Er werd een relatie gevonden tussen de aanwezigheid van tanderosie incisaal bij de melkincisieven boven en gebitsslijtage, en het beschadigen van rietjes tijdens consumptie.

Deze studies tonen aan dat veel jonge kinderen bij het drinken uit een pakje op het rietje bijten. Wanneer de tandarts gebitsslijtage bij de boven incisieven van kinderen constateert is het verstandig het mogelijke (foutieve) gebruik van rietjes met de ouders te bespreken.

Conclusie

Een algemene conclusie van dit proefschrift is dat veel factoren in de 21ste eeuw kunnen leiden tot tanderosie bij (jonge) kinderen en adolescenten. Kennis van de risicofactoren en beschermende factoren zijn een voorwaarde om tanderosie te voorkomen.

Vandaar dat ouders en kinderen uitgebreide en begrijpelijke informatie moeten krijgen over de risico's, die het eten en drinken van zure voedingsmiddelen met zich mee brengt, en ook advies moeten krijgen over eet- en drinkgewoonten die tandvriendelijk zijn.

Dankwoord

In 1993, tijdens een tandheelkundig congres in Chicago, heb ik in mijn ambitie om te promoveren serieus besproken. Op dat moment was er noch een kinderpraktijk, noch een onderwerp, laat staan sprake van wetenschappelijk onderzoek. Soms biedt het leven kansen, die je kunt grijpen en ben je, wanneer je achterom kijkt, verbaasd hoe het leven haar loop heeft genomen.

Promoveren, het heeft iets weg van wedstrijdroeien met coaches langs de kant en een stuurman in de boot. Doorzettingsvermogen, motivatie, techniek en discipline, in je eentje door weer en wind met start en eindsprint! Je moet wel een beetje gek zijn. Met één verschil, wanneer je de finish haalt, dan ben je ook een winnaar. Nu, de finish is gehaald: het proefschrift is af! Graag wil ik iedereen, die op enigerlei heeft bijgedragen aan mijn promotie hartelijk danken.

Door een samenloop van omstandigheden kwam ik in 1995 in contact met Prof.dr. Arie van Nieuw Amerongen. Het actuele probleem van tanderosie bij jonge kinderen en de toevallige ontdekking van erosief vloeibaar snoep resulteerde in een eerste onderzoek met Arie op de VU/ACTA op de afdeling Orale Biochemie (2006). Een wereld, waarin ik mij onder zijn begeleiding gauw thuis voelde.

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Curriculum Vitae

Dien Louise Gambon was born in The Hague, the Netherlands, on November 18th, 1960. She graduated in 1980 at the secondary school (Het Nederlandsch Lyceum) in The Hague. From 1981 to 1986 she studied dentistry at the University of Utrecht.

In the period 1986-1998 she worked at special dental care clinics (Stichting BIJTER, Rotterdam and IPSE, Nootdorp) and in a general dental practice. In 1990 she attended a course in 'special dental care' at the dental centre for postgraduate education in Jönköping, Sweden. In 1995 she started the 'Bambodino Kinderpraktijk', a private paediatric dental clinic in Rotterdam. In cooperation with a hospital in Rotterdam she is able to offer dental care to children under general anesthesia in daycare. In 2004 the paediatric dental clinic obtained the HKZ/ISO certification. In 2006 she was registered as a paediatric dentist and as a dentist specialized in treating patients with dental fear followed by her accreditation as a 'dentist special care' in 2008.

In 2001, by chance she became interested in the process of dental erosion in young children. In 2006 she started research on this topic at the department of Oral Biochemistry of VU/ACTA (Vrije Universiteit/Academic Centre Dentistry Amsterdam). The results of these studies have been described in this thesis.

She is a member of the Dutch Association of Paediatric Dentistry (NVvK) and was part of the Consilium Pedodontologicum for five years. She is also a member of the Dutch Association of Special Dental Care (VBTGG) and was the general secretary for several years. For the Rotterdam Dental Association (RTV) she served on the board of the committee organizing post graduate dental education for more than 12 years. Besides she is a member of the Dutch Dental Society (NTG).

Dien Gambon is married to Peter-Hans Henken and they have 2 children: Pieter (1997) and Martijn (2001).

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