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ORIGINAL ARTICLE

Prevalence of erosive tooth wear and associated risk factors in 2–7-year-old German kindergarten children

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OBJECTIVES: The aims of this study were to (1) investigate prevalence and severity of erosive tooth wear among kindergarten children and (2) determine the relationship between dental erosion and dietary intake, oral hygiene behaviour, systemic diseases and salivary concentration of calcium and phosphate.

MATERIALS AND METHODS: A sample of 463 children (2–7 years old) from 21 kindergartens were examined under standardized conditions by a calibrated examiner. Dental erosion of primary and permanent teeth was recorded using a scoring system based on O'Sullivan Index [*Eur J Paediatr Dent* 2 (2000) 69]. Data on the rate and frequency of dietary intake, systemic diseases and oral hygiene behaviour were obtained from a questionnaire completed by the parents. Unstimulated saliva samples of 355 children were analysed for calcium and phosphate concentration by colorimetric assessment. Descriptive statistics and multiple regression analysis were applied to the data.

RESULTS: Prevalence of erosion amounted to 32% and increased with increasing age of the children. Dentine erosion affecting at least one tooth could be observed in 13.2% of the children. The most affected teeth were the primary maxillary first and second incisors (15.5–25%) followed by the canines (10.5–12%) and molars (1–5%). Erosions on primary mandibular teeth were as follows: incisors: 1.5–3%, canines: 5.5–6% and molars: 3.5–5%. Erosions of the primary first and second molars were mostly seen on the occlusal surfaces (75.9%) involving enamel or enamel–dentine but not the pulp. In primary first and second incisors and canines, erosive lesions were often located incisally (51.2%) or affected multiple surfaces (28.9%). None of the permanent incisors ($n = 93$) or first molars ($n=139$) showed signs of erosion. Dietary factors, oral hygiene behaviour, systemic diseases and salivary calcium and phosphate concentration were not associated with the presence of erosion.

CONCLUSIONS: Erosive tooth wear of primary teeth was frequently seen in primary dentition. As several children showed progressive erosion into dentine or exhibited severe erosion affecting many teeth, preventive and therapeutic measures are recommended.

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Keywords: erosion; primary dentition; risk factor; salivary calcium/phosphate

Introduction

Dental erosion is defined as the loss of dental hard tissue due to the chemical influence of extrinsic and intrinsic acids without bacterial involvement (Imfeld, 1996). As caries has declined in many societies (Vehkalahti *et al*, 1997; Marthaler, 2004), an increasing attention has focused on tooth wear from erosion, abrasion and attrition. Although prevalence data on erosive lesions of the permanent dentition have been published in recent years (Nunn, 1996; Putz and Attin, 2002), prevalence surveys on dental erosion in the primary dentition have been documented less frequently and show varying results. Accordingly, the number of children exhibiting at least one tooth with erosive wear ranged from 30% to nearly 100% (O'Brien, 1993; Millward *et al*, 1994b; Jones and Nunn, 1995; O'Sullivan, 2000; Ganss *et al*, 2001; Al-Majed *et al*, 2002). However, the results of these studies are difficult to compare due to different diagnostic criteria and sample population. Ganss *et al* (2001) investigated erosive tooth wear of primary canines and molars using study models of orthodontic patients, which did not allow assessment of optical properties of enamel and very early stages of erosive lesions. Furthermore, due to a mean age of 11.4 years, only primary canines and molars were available for examinations. In most clinical epidemiological studies of

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dental erosion, only the primary maxillary incisors and maxillary first molars were included in the assessment (O'Brien, 1993; Hinds and Gregory, 1995; Al-Majed *et al*, 2002; Al-Malik *et al*, 2002). This procedure provides no information about the distribution of erosive lesions in the whole primary dentition. Moreover, some of these investigations used indices such as Smith and Knight Index (Smith and Knight, 1984), which is not especially designed for erosion diagnosis in general nor erosive lesions in primary dentition in particular. The National Child Dental Health survey (O'Brien, 1993) measured erosion only as a loss of enamel, dentine or exposure to pulp and was not sensitive to follow up subtle changes in tooth surface loss. Furthermore, evaluations of erosion in children have been largely confined to the UK (Millward *et al*, 1994a,b; Downer, 1995) and Saudi Arabia (Al-Malik *et al*, 2001, 2002; Al-Majed *et al*, 2002), but currently limited information about prevalence, severity and contribution of erosion in primary dentition of German children is available (Ganss *et al*, 2001).

As dental erosion has gained increased importance in dental research in the last few years, there is growing evidence available on the aetiology of erosive lesions. Dental erosion is regarded as a multifactorially induced disease with individual susceptibility factors related to extrinsic dietary acid and intrinsic sources of acid from gastrointestinal diseases (Järvinen *et al*, 1988; Milosevic *et al*, 1997). Risk factors studied include dietary habits, biological (e.g. saliva, acquired pellicle, tooth composition and dental anatomy) and behavioural (oral hygiene behaviour, eating and drinking habits) factors as well as socio-demographic data (Al-Dlaigan *et al*, 2001a,b, 2002a; Al-Malik *et al*, 2001; Lussi *et al*, 2004). The proportional contribution of these risk factors to the overall development of erosion in children is rarely investigated in epidemiological surveys. A comparison of prevalence data from cross-sectional national studies in the UK indicates that associations with aetiological factors like dietary intake, gastroesophageal reflux and socio-demographic variables are present but weak (Nunn *et al*, 2003).

The role of saliva in dental erosion is not fully understood, probably as a result of the complexity of inter- and intra-individual salivary conditions. Saliva is known to be important for protection against an erosive challenge by dilution and clearance of acidic products. One important role of saliva is the maintenance and protection of the dental hard tissues by providing a source of calcium and phosphate ions. It could be shown that subjects with erosion have less calcium and inorganic phosphate in saliva (Järvinen *et al*, 1991). Those individuals with low salivary calcium concentrations have a higher critical pH (pH-value at which hydroxyapatite starts to dissolve) and will therefore be more susceptible to demineralization than subjects with higher calcium concentrations (Järvinen *et al*, 1991). Therefore, the present study aimed to determine, if salivary inorganic factors alone or combined with other risk factors are useful predictors of erosive tooth wear.

In children with less mineralized hard tissue and extended pulp chambers, rapid loss of tooth structure probably leads to dentine hypersensitivity as well as pulpal inflammation and pulp exposure (Shaw and O'Sullivan, 2000). As a consequence, dental erosion may result in the destruction of the tooth crowns or early loss of teeth. This situation may affect mastication and biting as well as the development of speech or warrant orthodontic treatment. Further information is, therefore, needed not only to establish the extent of the problem in the general population, but also to quantify the need for preventive and restorative treatment of dental erosive tooth wear in primary dentition. Dental erosion occurring in the primary dentition is regarded as a predictor of an increased risk of erosive tooth wear in the permanent dentition (Ganss *et al*, 2001). Hence, examination of erosion-induced tooth structure loss in children seems to be important to allow for administration of preventive measures as early as possible.

Therefore, the aims of this first epidemiological study about erosively induced tooth wear in German kindergarten children were to (1) determine the severity and distribution of erosive lesions and (2) evaluate dietary habits, oral hygiene behaviour, systemic diseases and salivary concentration of calcium and phosphate as risk factors of dental erosion.

Materials and methods

Sample population and clinical investigation
All urban kindergartens (30 kindergartens) located in Göttingen, Germany, were invited to take part in the study. Nine kindergartens refused participation in the investigation. Therefore, 21 kindergartens from all geographical areas (north: six kindergartens, east: five kindergartens, south: four kindergartens, west: six kindergartens) were involved in the study. All children of these kindergartens (586 children) were invited to participate in the study. However, 123 children could not be included in the analysis. Either the children or the declaration of consent were absent at the visit, the questionnaires were not properly filled in or the children were unable to cooperate sufficiently. Therefore, the final group consisted of 463 (246 male and 217 female) children aged from 2 to 7 years. The number of children in the different geographical areas amounted to: north: 117, east: 147, south: 90, west: 109.

The parents/carers of the children gave written consent for the children to participate in this study. Prior to the visit, they got an information sheet about the aim of the study and were asked to answer a questionnaire. Ethical approval was given by the local Ethics Committee (No. 13/5/03).

All children were examined clinically by the same person who had previously undergone extensive training and calibration exercises in the use of the index. Calibration exercises were carried out before starting the study to ensure that the examiner was reliable and reproducible using the index. The surfaces of all teeth present in the mouth were scored for dental erosion according to the O'Sullivan Index (O'Sullivan *et al*, 1998; O'Sullivan, 2000) (Table 1). This index is especially designed for epidemiological surveys, diagnosis and treatment options of erosion in the primary dentition. In previous studies, reproducibility of the O'Sullivan Index was found to be comparable with other indices (O'Sullivan, 2000). Every tooth was examined for site of erosion, severity and area of surface affected and given a three-digit score (Table 1). For example, the score A3+ indicates that the erosion was on the labial surface only, the tissue loss was in enamel with the enamel–dentin junction visible, and more than the half surface was affected with this depth score. Loss of surface contour appearing flat and shiny was defined as abrasion and was therefore not included in the analysis. All data were recorded by a trained assistant.

Questionnaire
The questionnaire was developed in relation to the main erosive aetiological factors that have been published in literature and followed the UK National Clinical Guidelines in Paediatric dentistry (Shaw and O'Sullivan, 2000) and was based on multiple-choice questions. As a matter of course, the parents of the children were asked to fill out the questionnaire following an introduction from the investigator. The amount and frequency of consumption of fruit drinks, lemon tea, milk, lemonade, cola, water and citrus fruits as well as the type of infant feeding were recorded. The frequency of bedtime drinks and foods after toothbrushing were also included. Furthermore, the questionnaires covered details of medical history including gastrointestinal diseases, gastroesophageal reflux, frequent vomiting, diabetes and type and frequency of medication. Children with asthma were asked for the length of time of the disease and the type and duration of medication. Finally, oral hygiene habits such as time and frequency of toothbrushing as well as kind of toothbrush (electrical/manual) and toothpaste (concentration of fluoride) were assessed. The children were asked whether brushing was carried out with or without assistance. Also, current frequency of intake of fluoride tablets or mouthrinses were determined.

Table 1 Index for the measurement of dental erosion (O'Sullivan, 2000). Loss of surface contour appearing flat and shiny was defined as abrasion and was therefore not included in the analysis

Site on erosion on each tooth
Code A: Labial or buccal only
Code B: Lingual or palatinal only
Code C: Occlusal or incisal only
Code D: Labial and incisal/occlusal
Code E: Lingual and incisal/occlusal
Code F: Multi-surface
Grade of severity (worst score for an individual tooth recorded)
Code O: Normal enamel
Code 1: Matt appearance of the enamel surface with no loss of contour
Code 2: Loss of enamel only (loss of surface contour)
Code 3: Loss of enamel with exposure of dentine (EDJ visible)
Code 4: Loss of enamel and dentine beyond EDJ
Code 5: Loss of enamel and dentine with exposure of the pulp
Code 9: Unable to assess (e.g. tooth crowned or large restoration)
Area of surface affected by erosion
Code −: Less than half of surface affected
Code +: More than half of surface affected

Saliva investigation
Unstimulated saliva was collected from 355 children. Due to a lack of consent to participate in saliva analysis, salivary samples of 108 children could not be obtained.

Saliva sampling was carried out in the morning between 10.30 and 11.30 h. The children were advised not to drink or eat for 2 h prior to collection. After an initial swallow of saliva, unstimulated saliva was obtained by passive dripping into a test beaker during 5 min with the subjects sitting in a relaxed upright position. The samples were stored at −20°C within 30 min of collection and remained there until determination of Ca and P content.

Both calcium and phosphate concentrations were colorimetrically assessed in a microplate reader at 650 nm (Molecular Devices, Ismaning/Munich, Germany). Colorimetric assessments were performed at room temperature within 30 min after mixing of the reagents and the diluted salivary samples.

Preparation of saliva for measuring calcium concentration was conducted with the calcium Arsenazo III method (Smith and Bauer, 1979). Arsenazo III reacts with calcium to form a blue–purple complex. The intensity developed is proportional to the calcium concentration and could be determined photometrically according to the Lambert–Beer law. Reagent for determination is composed of 100 mmol l^{-1} Imidazol buffer (pH 6.5) and 0.08 mmol Arsenazo III (Fluitest® Ca – A III; Biocon Diagnostik, Vöhl, Germany). Saliva was diluted with distilled water in a ratio of 1:11. Ten microlitres of the diluted saliva was admixed to 100 μl of the Arsenazo III reagent.

Salivary phosphate concentration was determined according to the procedure developed by Fathi *et al* (2002). For this purpose, 0.045 mg malachite green dissolved in 100 ml aqua bidest was admixed to 12.69 g ammonium molybdate dissolved in 300 ml HCl (4 mol l^{-1}). The reagent was stirred for 30 min afterwards and filtered; 200 μl of the phosphate assay was admixed to 3 μl saliva (prior diluted with distilled water, 1:11). Malachite green reacts with phosphate to a coloured complex which can be determined at $\lambda = 650$ nm.

Statistical analysis
Both descriptive and analytical approaches were used in the data analysis. Descriptive statistics was performed on the data from the clinical investigation. Analysis of questionnaire items was performed by multiple logistic regression analysis. As dependent variable, an individual factor based on the mean value of amount and area of affected surfaces and grade of severity of erosion in the whole dentition was assigned to each child. Multiple logistic regression analysis with a stepwise selection procedure was used to investigate the influence of dietary patterns and oral hygiene practices to the outcome of erosion. Thereby, the criterion for the

independent variables to enter the model was set at 0.2 and the criterion to stay at 0.25. Level of significance was set at $P \le 0.05$. *T*-test ($P \le 0.05$) was used to assess the relationship between calcium and phosphate concentration and dental erosion. Due to the fact that only 355 saliva samples could be obtained, the results of saliva investigation were not included in multiple regression analysis.

Results

Clinical examination

Of the 463 children, 148 children (32%) had at least one tooth showing signs of erosive tooth wear. Thereby, 5376 primary incisors and canines and 3669 molars were under investigation. Of these 9045 teeth, 124 incisors and/or canines and 190 molars could not be examined because of extensive caries, large restoration or tooth crown, and were not included in the analysis.

Only a small difference in prevalence of erosion between girls (61 of 217, 28.1%) and boys (87 of 246, 35.5%) existed. The number of children exhibiting erosive lesions according to the age groups is seen in Table 2. It is obvious that prevalence of dental erosion in primary dentition increases with increase of children's age: 2–3 years old: 23.8%, 4 years old: 27.4%, 5 years old: 30.4% and 6–7 years old: 39.5% (Table 3).

Most of the children ($n = 101$) showing erosive tooth wear ($n = 148$) had one to five teeth exhibiting erosive tooth wear, 38 children had six to 10 teeth showing signs of erosion and only nine children showed more than 11 teeth with dental erosion (Table 2). Moreover, 61 of 148 children had at least one tooth with erosive tooth wear which affects dentine or pulp (61 of 463 children, 13.2%). Progressive tooth wear into dentine was more frequently seen in children exhibiting more than 11 teeth with dental erosion (seven of nine children) as in children showing six to 10 affected teeth (21 of 38 children) or one to five affected teeth (33 of 101 children). Totally, most children showed erosive tooth wear on incisors and/or canines only ($n = 104$). In 10 children, only maxillary or mandibulary molars were affected from erosion and 34 children showed erosive lesions in both incisors/canines and molars.

The most frequently affected upper teeth were the primary first and second incisors (15.5–25%) followed by the canines (10.5–12%) and molars (1–5%). Erosion on primary mandibular teeth was distributed as follows: incisors: 1.5–3%, canines: 5.5–6% and molars: 3.5–5% (Figure 1).

Erosion of the primary first and second molars was mostly seen on occlusal surfaces only (75.9%) involving enamel or enamel–dentine, but not the pulp. In primary first and second incisors and canines, erosive lesions were often located on incisal surfaces (51.2%) or affected multiple surfaces (28.9%) (Table 4a,b). It was obvious that a quarter ($n = 35$) of the erosively affected incisors and canines ($n = 133$) and nearly a third ($n = 175$) of the erosively affected molars ($n = 567$) showed tooth wear which exposed dentine.

None of the permanent incisors ($n = 93$) or first molars ($n = 139$) of 40 children exhibiting mixed dentition showed signs of erosive tooth wear.

Table 2 Children exhibiting dental erosion and number of affected teeth in relation to the age group. For 24 children, the age was not known exactly, as their parents neglected to mark it on the questionnaire

Age group	*Total no. of children affected from erosion*	*Children affected from erosion*	*1–5 teeth*	*6–10 teeth affected from erosion*	*11–15 teeth affected from erosion*
2 years old	2	1	1	0	0
3 years old	40	9	8	1	0
4 years old	117	32	22	9	1
5 years old	141	43	31	11	1
6 years old	134	51	29	15	7
7 years old	5	4	3	1	0
Children without specification of age	24	8	7	1	0
Total	463	148	101	38	9

Table 3 Percentage distribution of primary teeth (no. 55–85) exhibiting dental erosion in the different age groups. Children without specification of age ($n = 24$) were not included

	Primary tooth									
Age group	*55*	*54*	*53*	*52*	*51*	*61*	*62*	*63*	*64*	*65*
2–3 years old	0	4.8	4.9	11.9	21.4	21.4	9.5	0	2.4	0
4 years old	2.6	4.3	6.8	13.8	19.8	20.9	14.6	2.6	6.0	2.6
5 years old	1.4	5.7	12.1	14.3	19.6	23.2	18.6	12.1	5.0	1.4
6–7 years old	1.4	6.7	21.7	20.1	30.5	31.1	23.1	21.9	6.7	1.5
	85	84	83	82	81	71	72	73	74	75
2–3 years old	0	0	0	0	0	0	0	0	0	2.4
4 years old	2.6	6.0	6.0	2.6	3.4	3.4	2.6	6.0	4.3	2.6
5 years old	2.1	4.3	2.8	0.7	2.2	2.2	0.7	3.5	4.3	2.9
6–7 years old	6.7	6.5	9.4	3.0	6.1	6.3	3.7	10.1	6.7	3.1

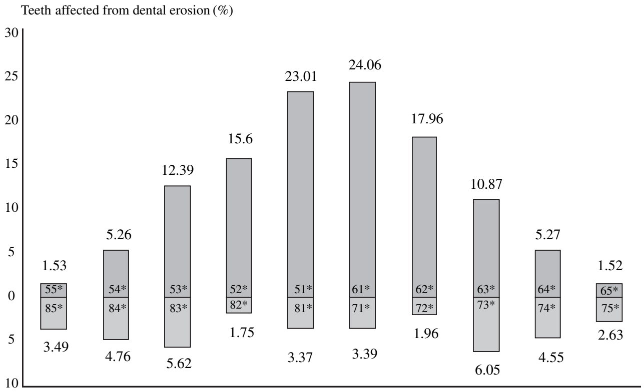

Figure 1 Percentage of primary teeth (no. 55–85)* affected with any sign of dental erosion

Table 4 Distribution (*n*) of the teeth showing erosion with regard to severity (0–9), localization (A–F) and area (+/−) of erosively affected surfaces in the primary dentition of maxillary and mandibulary first and second incisors and canines (a) and first and second molars (b) according to the criteria of O'Sullivan Index (O'Sullivan, 2000)

	A		*B*		*C*		*D*		*E*		*F*		*Total*	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−
(a)														
1	12	22	11	3	23	14	1	0	3	0	17	0	67	39
2	6	0	21	3	105	59	0	0	2	2	59	0	159	64
3	2	0	21	4	71	18	0	0	0	0	59	0	153	22
4	0	0	0	0	0	0	0	0	0	0	60	1	60	1
5	0	0	0	0	0	0	0	0	0	0	2	0	2	0
Total	20	22	53	10	199	91	1	0	5	2	163	1	567	
(b)														
1	1	0	0	1	2	21	0	0	0	0	0	0	3	22
2	0	0	0	3	14	38	0	0	0	0	7	1	21	42
3	0	0	0	0	21	3	0	0	0	0	5	0	26	3
4	0	0	0	0	2	0	0	0	0	0	14	0	16	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	0	0	4	39	62	0	0	0	0	26	1	133	

Questionnaire/associated risk factors

The evaluation of the questionnaire showed no evidence for systemic diseases or medication to act as a risk factor for dental erosion. None of the participants revealed systemic diseases related to frequent vomiting or hyposalivation/xerostomia. Six children used an inhalation spray because of asthma. Two of these six children showed signs of dental erosion. Only one of 463 children showed gastroesophageal reflux disease and dental erosion. Due to this low number involved, statistical analysis was not performed on these factors.

The possible association between erosion and the dietary and oral hygiene data were analysed by multiple logistic regression analysis (Table 5). Thereby, the criterion to enter was set at 0.2 and the criterion to stay at 0.25. However, most variables failed the final model. The final model included only two variables: consumption of lemon tea ($P = 0.076$) and brushing with/without assistance of the parents ($P = 0.068$). However, both variables failed significance and, therefore, odds ratios and confidence intervals were not calculated. In conclusion, dietary and oral hygiene data were not associated with the amount and area of affected surfaces and grade of severity of dental erosion.

Table 5 Independent variables included in the multiple logistic regression model. Due to the failure of significance of all variables ($P > 0.05$), odds ratios and confidence intervals were not calculated. Variables marked by * were included in the final model but *P*-value also failed significance

Model
Frequency of drinks (fruit drinks, lemon tea*, milk, lemonade, cola, water)
(0 = never, 1 = weekly, 2 = daily, 3 = 2–3 daily, 4 = more than 3 daily)
Frequency of citrus fruits
(0 = never, 1 = weekly, 2 = daily, 3 = 2–3 daily, 4 = more than 3 daily)
Type of infant feeding by baby bottle
(0 = without erosive potential, 1 = with erosive potential)
Duration of acidic infant feeding by baby bottle
(0 = none, 1 = up to 6 months, 2 = 6–12 months, 3 = 12–18 months, 4 = more than 18 months)
Duration of breast feeding
(0 = none, 1 = up to 6 months, 2 = 6–12 months, 3 = 12–18 months, 4 = more than 18 months)
Frequency of acidic bedtime drinks and foods after toothbrushing
(0 = never, 1 = weekly, 2 = daily, 3 = monthly)
Frequency of systemic fluoridation by fluoride tablets
(0 = never, 1 = weekly, 2 = daily, 3 = monthly)
Frequency of application of fluoridated mouthrinses
(0 = never, 1 = weekly, 2 = daily, 3 = monthly)
Frequency of toothbrushing
(0 = never, 1 = daily, 2 = twice daily, 3 = thrice daily, 4 = twice-thrice weekly)
Duration of toothbrushing
(1 = 1 min, 2 = 2 min, 3 = 3 min)
Kind of toothbrush
(1 = manual toothbrush, 2 = power toothbrush, 3 = both manual and power toothbrush)
Kind of toothpaste
(0 = non-fluoridated toothpaste, 1 = fluoridated toothpaste)
Toothbrushing performed by*
(1 = the child, 2 = the parents, 3 = both child and parents)

Saliva concentration of calcium and phosphate

Mean calcium and phosphate concentration in unstimulated saliva of 355 children amounted to 1.65 ± 0.83 and 6.74 ± 2.86 mmol l^{-1}, respectively. *T*-test revealed no significant differences in salivary calcium and phosphate concentration between children with or without erosive tooth wear. Moreover, children exhibiting erosion into dentine differed not significantly from children without any erosive lesions.

Discussion

Enamel and dentine structure of deciduous teeth are different from permanent dental hard tissues. Enamel and dentine layers of primary teeth are known to be thinner than those of their permanent successors and demonstrate a lower degree of mineralization (Wilson and Beynon, 1989). Furthermore, deciduous enamel shows a higher degree of enamel porosity (Fejerskov *et al*, 1987) and a different mineral content compared with permanent tissue (Cutress, 1972). Therefore, several *in vitro* studies have investigated the demineralization behaviour of deciduous compared with permanent dental hard tissues (Hunter *et al*, 2000a,b; Lussi *et al*, 2000). The outcome of these studies were contradictory, showing either a higher susceptibility of deciduous enamel to erosion (Amaechi *et al*, 1999) or no differences in their demineralization behaviour (Lippert *et al*, 2004). Nevertheless, after an erosive attack, microhardness of primary enamel seems to be significantly lower compared with that of permanent enamel leading to an decrease of abrasion resistance (Johansson *et al*, 2001; Johansson, 2002).

The prevalence of erosive tooth wear in the present study population amounted to 32% and is therefore considerably higher compared with the prevalence data of the permanent dentition ranging from 4 to 25% (Lussi *et al*, 1991; Putz and Attin, 2002).

Our prevalence data are very close to the data of the studies of Al-Malik *et al* (2001, 2002) and Harding *et al* (2003), who found that 31% of 2–5-year-old children or 42% of 5-year-old children, respectively, had erosively affected maxillary incisors. In contrast, the prevalence data do not agree with the results of the UK Children's Dental Health Survey (O'Brien, 1993) and the epidemiological study in Saudi Arabian children (Al-Majed *et al*, 2002). They reported 50–80% of the maxillary incisors being affected from erosion. Recently, Jaeggi and Lussi (2004) found all of the 5–9-year-old Swiss children under examination being affected from at least one tooth with erosive tooth wear. The differences in the prevalence data between these studies may be partly explained by the differences in diagnostic criteria and indices and varying socioeconomical, cultural and geographical factors which could influence the outcome of prevalence data. Moreover, most of the epidemiological studies used 'marker teeth' to analyse erosion. However, focusing only on incisors or first molars provides no information about the distribution and severity of erosive lesions in the whole dentition. Finally, populations of case–control studies are not representative of the whole population.

Many epidemiological surveys found an increase of dental erosion of permanent teeth with increasing age. The results of this study show that this is also true for the primary dentition. Generally, all teeth of the primary dentition could be affected from erosion. However, distribution, severity and amount of affected tooth area were very different when comparing maxillary and mandibulary teeth or incisors/canines and molars.

It is obvious that most of the children affected from erosion, exhibited only few teeth with erosive tooth wear, and only few individuals showed severe erosion, which affects nearly the whole dentition and was often associated with progression into dentine. It could be assumed that the distribution of erosive lesions in primary dentition is confined to a little group of children which are affected from severe erosion, whereas the majority shows little or no signs of dental erosion.

Tooth wear in upper and lower jaw were distributed symmetrically. The most affected maxillary teeth were the first and second incisors, followed by the canines and molars. In contrast, in the lower jaw, canines and molars were more often affected from erosive tooth wear than the incisors. The finding that the upper incisors were affected predominantly, could be explained by the fact that these are the first erupting teeth, which, as a consequence, are exposed to erosive challenges for a longer period of time. Moreover, the location of incisors and canines in the oral cavity, makes them predisposable to erosion by extrinsic acids such as acidic beverages. Possibly, lower incisors were not affected due to the covering and protecting of their labial surfaces by the maxillary incisors and the potential for neutralization by saliva excreted by the submandibular and sublingual salivary glands. These facts may explain the low prevalence of erosion in the mandibular incisors. It may be assumed that due to the late eruption of the primary molars the prevalence of erosive tooth wear was distinctly lower compared with incisors and canines.

The occlusal surfaces of the molars and incisal surfaces of the incisors were the tooth surfaces showing highest degree of erosive tooth wear. Furthermore, in both tooth groups (incisors/canines and molars) erosion affecting multiple surfaces was often seen. Oral surfaces of these teeth were less frequently involved, and vestibular surfaces were rarely affected.

It has to be taken into consideration that tooth wear is a cumulative multifactorial process including erosion, abrasion and attrition. Attrition of incisal edges in the primary dentition is very common at the time of exfoliation, and it is extremely difficult to clearly distinguish erosion from attrition in the late stages of the primary dentition. Therefore, many studies excluded incisal and occlusal surfaces as wear was considered to be rather due to attrition than to erosion. As abrasion resistance of eroded primary enamel is significantly lower compared with permanent dental hard tissues, it is possible that erosive damage of dental hard tissue is also mechanically enhanced by attrition. Although there is always a mechanical component of abrasion, incisal tooth wear appearing as matt surface is mainly due to erosion. In the present study, incisal loss of surface contour appearing flat and shiny was defined as abrasion and were therefore not included in the analysis.

The questionnaire covered a number of dietary items, medical factors and oral hygiene habits reported to be related to erosion (Al-Dlaigan *et al*, 2001a, 2002a). Multiple regression analysis was performed with the data, contributing to the fact that determinants are unlikely to have completely independent effects.

None of the dietary factors emerged as significant in relation to erosion. These results appear to agree with the findings of the review of British National children's surveys (Nunn *et al*, 2003), where no statistically significant relationships but only some trends were seen between erosion and dietary factors.

Al-Dlaigan *et al* (2002a) reported only a weak association between dental erosion in 14-year-old children and oral hygiene practices. This was also seen in the present study. Neither toothbrushing habits such as frequency, duration and type of brush, nor local or systemic fluoridation were statistically correlated with dental erosion. It should be noted that questionnaires used in cross-sectional studies have limitations and bear the possibility of some self-reporting bias. Nevertheless, the results of the questionnaire analysis indicate that none of the dietary and oral hygiene factors act as risk factors in general. It could be assumed that other factors such as cultural, social and occupational and inter- and intraindividual host factors might be relevant.

Few studies have been published dealing with the salivary factors which may influence dental erosion, but found different results concerning a possible relation between salivary flow rate, buffering capacity and pH-value (Bartlett *et al*, 1998; O'Sullivan and Curzon, 1998; Anderson *et al*, 2001; Al-Dlaigan *et al*, 2002b). However, saliva is composed of a variety of electrolytes, including calcium and phosphate which contribute to the maintenance of tooth integrity.

There have been very few studies comparing salivary calcium and phosphate concentrations in children and adults and relating these to susceptibility to erosion. Anderson *et al* (2001) measured calcium and phosphate concentrations in rested and unstimulated saliva of 6–12-year-old children and noted that the driving force for de- and remineralization is governed by salivary pH-value and calcium concentration. Thereby, individuals with lower salivary calcium concentrations exhibit a higher critical pH for hydroxyapatite dissolution and a lower driving force for remineralization. For subjects showing dental erosion, Järvinen *et al* (1991) found less calcium and phosphate in the saliva, possibly related to a reduced production of unstimulated saliva.

This is the first time to our knowledge that the amount of salivary calcium and phosphate has been included in an epidemiological study aimed at an assessment of erosion risk in 2–7-year-old children. However, the results indicated that there is no difference between children with and without erosive tooth wear with respect to salivary calcium and phosphate. Salivary calcium and phosphate concentrations found in the present study (Ca: 1.65 mmol l^{-1}, P: 6.74 mmol l^{-1}) were similar to values reported previously. Electrolyte concentration in unstimulated saliva of infants aged 2 days to 12 months amounted to 1.5–2 mmol l^{-1} calcium and 2.3–3.9 mmol l^{-1} phosphate (Ben Aryeh *et al*, 1984). In children aged from 6 to 12 years calcium concentration of resting saliva ranged from 0.2 to 0.7 mmol l^{-1}. Concentration of phosphate amounted to 2.5–6.5 mmol l^{-1} (Anderson *et al*, 2001).

The results of the saliva analysis in the present study indicate that electrolyte concentration does not act as predictor for dental erosion in children. This is also confirmed by the results of Johansson *et al* (2002) who found no differences in calcium and phosphate concentrations of high- and low-erosion groups of adult volunteers.

Conclusions

The results of the present study indicate that erosive tooth wear is a problem in children which must not be underestimated.

Dental erosion of primary dentition was seen in a third of the children, but severity and amount of affected teeth were unevenly distributed. Especially for the children who show severe erosion, accurate measures of identifying these 'at-risk individuals' at an early age are necessary. However, neither dietary and oral hygiene factors nor systemic diseases or salivary electrolyte concentration were found to act as a risk indicator in general.

As erosion of primary teeth is considered to be a predictor for erosion and general tooth wear of the permanent dentition (Ganss *et al*, 2001), precise preventive and therapeutic measures are necessary to avoid increasing clinical problems.

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