

Dental erosion in children and adolescents – a cross-sectional and longitudinal investigation using study models

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Abstract – Objective: To investigate the prevalence and incidence of dental erosion in children and adolescents. **Methods:** Lesions were registered for all tooth surfaces of primary and permanent teeth using pre-orthodontic study models. A total of 1000 individuals (mean age 11.4 ± 3.3 years) were included; 265 of them were followed over a 5-year period using their final orthodontic casts. **Results:** In the primary teeth, 26.4% of the individuals had no erosive lesions, 70.6% had at least one tooth with grade 1 erosion and 26.4% had grade 2 erosion. Grade 1 erosion was found in 44% of the occlusal surfaces of molars (36% of the incisal surfaces of the canines) and grade 2 erosion in 11% (9%). Lesions affecting oral or vestibular surfaces were negligible. In the permanent teeth, 11.6% of individuals had at least one tooth with grade 1 erosion but only 0.2% had at least one tooth with grade 2 erosion. The most affected teeth were the mandibular first molars (7% with grade 1 lesions). Lesions affecting oral or vestibular surfaces were negligible. Mandibular first molars were identified as possible marker teeth for the onset of erosive lesions. Within the last two decades, the percentage of subjects with at least one tooth with a grade 1 or 2 erosive lesion significantly increased for primary and with grade 1 for permanent teeth ($P \leq 0.001$). The longitudinal observation revealed that subjects with erosive lesions in their primary dentition had a significantly increased risk for erosion in their permanent teeth ($P \leq 0.001$). **Conclusion:** In Germany, dental erosion seems to be a significant, but not a serious, problem for dental health in adolescents.

Key words: erosion; prevalence; primary teeth; permanent teeth

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During the last decade, only a few prevalence surveys on dental erosion in the general population have been published (1–4). Most studies have focused on small series of subjects with a potential risk for erosive lesions due to profession, impairments of general health or lifestyle (5–7) or are case reports (8), whereas other investigators refer to tooth wear in general and not to dental erosion in particular (9).

In children, prevalence studies on non-caries-caused dental lesions have reported striking but contradictory prevalence data. In a group of 11–14-year-old schoolchildren, 57% had tooth wear on 10

permanent teeth or more, but the involvement of dentin was rare (10). In contrast, in a random sample of 1035 14-year-old children, 30% already had exposed dentin in the permanent dentition (9). Only two studies have focused on the prevalence of dental erosion, in particular reporting that 8% of the 1.5–4.5-year-olds and nearly a quarter of the 5–6-year-olds were affected with erosive lesions exposing dentin (1, 2).

However, the comparison and interpretation of prevalence studies on tooth wear or dental erosion is difficult because multiple indices are used. In contrast to dental caries, age has to be taken into

account if a given lesion is to be judged as pathological or not. A lesion involving dentin may be interpreted as pathological in an adolescent, while the same lesion at older ages may be taken as a reflection of normal wear over the lifespan. This holds true for all features of tooth wear where "the distinction between acceptable and pathological wear at a given age is based on the prediction of whether the tooth will survive the rate of wear" (11). Therefore, focusing on the prevalence of dental erosion in children or young adults may be most relevant for the assessment of the present implication of erosive lesions for oral health.

In contrast to dental caries requiring restorative intervention when a significant cavitation had occurred, an erosive lesion normally does not need further treatment if the causative agent is eliminated or substance loss is arrested by sufficient prophylactic measures. Particularly at an early age, information should be given to the patients as soon as the first signs of erosion are diagnosed. Therefore, it would be helpful to identify "marker teeth" that are the first to be affected, as well as to assess whether erosive lesions in primary teeth may be a predictor for a possible risk for erosion in permanent teeth.

Taking the number of publications into account, the scientific interest in dental erosion has dramatically increased in the last few years. Additionally, a growing awareness of dental erosion during clinical work gives the impression that the prevalence of erosive defects is increasing. However, to date there are no data available to support this assertion.

Therefore, the aim of the present study was (a) to evaluate the prevalence of dental erosion in the primary and permanent dentition of children and adolescents, (b) to clarify if erosive lesions are an increasing risk for dental health in general, (c) on an individual basis, to identify "marker teeth" which may allow a timesaving screening procedure during a routine dental examination, and (d) to assess if erosive lesions in primary teeth may be a predictor for erosive lesions in the permanent dentition, allowing early diagnosis of subjects at risk.

Material and methods

Analysis of the study models

Dental erosive lesions were diagnosed using orthodontic study models. For the cross-sectional prevalence study, 1000 pre-orthodontic casts taken

during 1977–1999 were included. All of them were made from alginate impressions and only study models of excellent quality were used. For the longitudinal evaluation, final orthodontic casts were included if they were taken at least 5 years after the initial cast. Mean age and sex of the included subjects is presented in Table 1. No additional information regarding socioeconomic data, nutrition or general health was available.

Erosive lesions were recorded on vestibular, oral and occlusal/incisal surfaces of primary and permanent teeth. Due to a mean age of 11.4 years, only canines and molars were available for judgment concerning the primary dentition; for the permanent dentition, all teeth were included. However, incisal surfaces of permanent incisors and canines were excluded due to severe uncertainties of diagnostic criteria.

The criteria were defined as follows, modified from the scoring system of Linkosalo & Markkanen (12).

Vestibular/oral surfaces

Concavities located coronally from the enamel-cementum junction, the breadth of which greatly exceeds their depth, thus distinguishing them from wedge-shaped defects, Grade 0: no visible erosion, Grade 1: shallow concavities less than one third of the surface, Grade 2: deep concavities or shallower concavities both more than one third of the surface.

Occlusal surfaces

Grade 0: no visible erosion, Grade 1: small pits and slightly rounded cusps, fissures flattened, moderate cupping, occlusal surface morphology preserved, Grade 2: depression of the cusps with severe cupping and grooving, restoration margins raised above the surrounding tooth level, occlusal surface morphology flattened.

Facets (attrition) defined as flat areas with clear-cut borders and with corresponding wear of the antagonists were excluded.

In addition, an "erosion index" (EI) was determined for the permanent dentition of each subject:

$$EI = \frac{\sum \text{of number of surfaces with an erosive lesion}}{\sum \text{of the total number of surfaces at risk}} \times 100$$

The analysis of the study models was performed by the same examiner (K.G.), who was calibrated by one independent examiner (C.G.). Before the beginning of the study, she was extensively trained and exemplary study models served as corrective

Table 1. Number, mean age and sex of the subjects included

	<i>n</i>	Mean age±SD (years)	Male	Female
Cross-sectional study	1000	11.4±3.3	458	642
<1990	398	11.3±3.4	188	210
≥1990	602	11.4±3.3	270	332
Longitudinal study				
Initial		10.2±2.3		
Final	265	15.8±2.5	124	141

measures to minimize shifts in the assessment during the examination period. The casts were examined in random order and under excellent light conditions. No magnification aid was used. The Kappa values for intraexaminer reliability ranged between 0.9 and 1.

Statistics

The data were fed into a database created with Access 2.0 and then transferred to the Statistical Package for Social Sciences (SPSS 8.0) for statistical procedures.

Cross-sectional assessment

On the individual basis, differences of the erosion index or of the number of subjects with at least one tooth with an erosive lesion between the observation periods (1977–1989 and 1990–1999) were evaluated using the Mann-Whitney test. To compare the prevalence of dental erosion occurring during the two test decades as far as all teeth was concerned, cross tabulations and the chi-square test were used.

Longitudinal assessment

For the longitudinal assessment of the incidence of dental erosion over the 5-year period the erosion index as well as the number of subjects with at least one tooth with an erosive lesion at both mean age 10 and mean age 15 were compared using the Wilcoxon test.

To evaluate the association between erosive lesions in primary and permanent teeth, cross tabulations and the chi-square test were used. In addition, the relative risk (RR) was determined, expressed as

$$RR = \frac{\text{incidence of erosion of permanent teeth in subjects with erosion in primary teeth}}{\text{incidence of erosion of permanent teeth in subjects without erosion in primary teeth}}$$

Individuals were described as “subjects with dental erosion” if they had at least one tooth with a grade 1 or 2 erosive lesion.

Results

Cross-sectional assessment

For the cross-sectional assessment of the prevalence of erosive lesions, 1000 pre-orthodontic study models were analyzed. In two of them a complete primary and in 207 a complete permanent dentition was present; therefore, 998 casts were available for the assessment of permanent teeth and 793 casts for the assessment of primary teeth.

Primary teeth

Dental erosion was common on the occlusal/incisal surfaces of primary teeth. Grade 1 lesions were found in 44% of the occlusal surfaces of molars (36% of the incisal surfaces of the canines) and grade 2 lesions in 11% (9%). Grade 1 lesions were found in 36% of canines and grade 2 lesions in 9%. In contrast, erosive lesions affecting palatal or vestibular surfaces were negligible (<0.5%).

On the individual level, 26.4% of the subjects had no erosive lesions, whereas 70.6% had at least one primary tooth with grade 1 erosion and 26.4% with grade 2 erosion.

From 1977–1989 to 1990–1999 the prevalence of erosion in primary teeth doubled ($P \leq 0.001$, Fig. 1). In the 1980s, 25% of the molars and 23% of the canines had grade 1 and 7% and 5%, respectively, had grade 2 lesions. One decade later, 55% of the molars and 45% of the canines had grade 1 and 13% or 11%, respectively, had grade 2 lesions (Fig. 1). Even the percentage of subjects with at least one tooth with a grade 1 or 2 erosive lesion significantly increased ($P \leq 0.001$, Table 2).

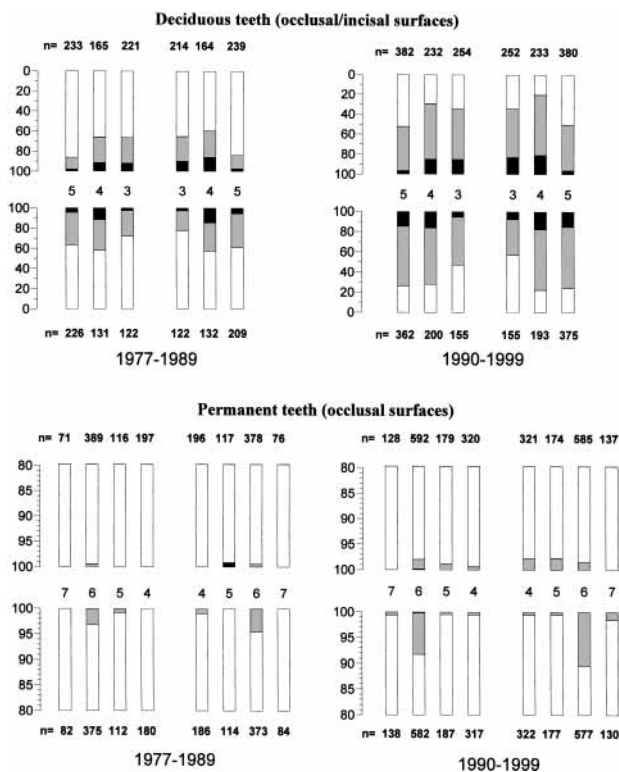


Fig. 1. Distribution pattern of erosive lesions on occlusal/ incisal surfaces of primary teeth and on occlusal surfaces of permanent teeth expressed as percentage of lesions grade 0 (white columns), grade 1 (gray columns) and grade 2 (black columns) of total surfaces at risk from 1977–1989 and from 1990–1999. n =total number of teeth evaluated.

Permanent teeth

In contrast to primary teeth, erosive lesions occurring on occlusal surfaces of permanent teeth were rare. Regarding grade 1 lesions, the most affected teeth were the right (8%) and left (6%) mandibular first molars. Grade 2 occlusal lesions as well as erosive lesions on palatal and vestibular surfaces were negligible (<0.5%).

On the individual level, 88.4% of the subjects had no signs of erosive lesions, 11.6% had at least one tooth with grade 1 erosion and 0.2% had at least one tooth with grade 2 erosion. The mean erosion index was 0.4 ± 1.3 (maximum 10.6).

Even in permanent teeth an increase of erosive lesions was observed during the last decade. In the 1980's, 3.9% of the mandibular first molars had grade 1 lesions, whereas no grade 2 lesions were observed. In the 1990's, 9.3% of the mandibular first molars had grade 1 erosion and 0.1% grade 2 ($P \leq 0.001$, Fig. 1). Correspondingly, the percentage of subjects with at least one tooth with a grade 1 erosive lesion as well as the erosion index significantly increased ($P \leq 0.001$, Table 2). Even the

number of subjects with at least one tooth with a grade 2 lesion increased, but this failed to reach statistical significance.

In the group of subjects with erosive lesions at a mean age of 11.4, 87.1% had occlusal lesions in their left or right mandibular first molars; in the remaining 12.9% the lesions (mostly singular) were distributed over other tooth groups. At a mean age of 15.8, even 93.5% had their mandibular first molars affected, with only 6.5% having erosive lesions located in other tooth groups.

Longitudinal assessment

For the longitudinal assessment of the incidence of dental erosion, 265 subjects with initial and final casts available were studied.

Within 5 years, the number of individuals with signs of grade 1 and grade 2 erosion as well as the erosion index, which expresses the percentage of surfaces with erosive lesions per subject, approximately quadrupled (Table 3). The most marked increase was noted for lesions in mandibular first molars. At a mean age of 10.2, grade 1, but no grade 2, lesions were observed in 2.4% of the molars; 5 years later 17.3% had grade 1 lesions and 0.6% grade 2 lesions. In maxillary first molars, grade 1 lesions increased from 0.4% to 4.1%; grade 2 lesions were not observed. The increase in lesions affecting other tooth groups or tooth sides was negligible.

Subjects with erosive lesions in their primary dentition had an increased risk (relative risk of 3.9) for erosion in their permanent teeth ($P \leq 0.001$). In children with lesions in their primary teeth, only 66.0% had no lesions in their permanent teeth. In contrast, of the subjects who exhibited no erosive lesions in their primary dentition, 91.2% had no lesions in their permanent dentition.

Discussion

The striking prevalence data for dental erosion in primary as well as in permanent teeth reported for British schoolchildren could not be validated for Germany in the present study. The National Survey of Child Dental Health (2) reported that more than half of the 5–6-year-olds exhibited erosion of the smooth surfaces (occlusal/incisal surfaces were excluded), and the dentin was involved in nearly a quarter. A similarly conducted study on 1.5–4.5-year-olds using the same criteria revealed that 10% of the children had erosive lesions of the buccal and 19% of the palatal surfaces of their incisors and

Table 2. Prevalence of erosive lesions in the primary and permanent dentition (cross-sectional)

	<i>n</i>	Subjects with no erosion (%)	Subjects with at least one tooth grade 1 (%)	Subjects with at least one tooth grade 2 (%)	Mean EI±SD (max.)
Primary					
1977–1989	320	46.6***	52.2***	17.5***	–
1990–1999	473	12.7***	83.1***	32.3***	–
Total	793	26.4	70.6	26.4	–
Permanent					
1977–1989	397	93.7***	6.3***	0.3	0.2±0.9 (7.7)***
1990–1999	601	84.9***	15.1***	0.2	0.5±1.5 (10.6)***
Total	998	88.4	11.6	0.2	0.4±1.3 (10.6)

*** Significant differences ($P \leq 0.001$) between the observation periods.

Table 3. Incidence of erosive lesions in permanent teeth within 5 years (longitudinal)

	<i>n</i>	No erosion	At least one tooth grade 1	At least one tooth grade 2	Mean EI±SD (max.)
Subjects at a mean age of 10.2±2.3	265	94.7%***	5.3%***	0.4%	0.2±1.8 (7.7)***
Subjects at a mean age of 15.8±2.5	265	77.0%***	23.0%***	1.5%	0.7±1.8 (16.7)***

*** Significant differences ($P \leq 0.001$) between the different ages.

in 8% the dentin was affected (1). In contrast, in the present study, lesions affecting the smooth surfaces of primary teeth were found to be negligible despite the older age of the selected group. This may partly be explained by the fact that in the British studies the lesions seemed to be mainly located in the incisors, which were not available for study in the present investigation. Even in the permanent dentition, significant prevalence data for erosive lesions affecting smooth surfaces were reported. For subjects over 11 years of age, nearly a quarter had moderate signs of erosion and 2% had lesions affecting dentin (2). Again, this is in contrast to the results of the present study, where lesions affecting the smooth surfaces were negligible. The differences may at least partly be attributed to the use of study models compared to a clinical approach. The advantage of using casts is that the evaluation can be performed repeatedly and under optimal illumination, viewing them from all sides and without any pressure of time. In addition, an excellent assessment of occlusal surfaces and the occlusal relation is possible (13). However, the optical properties of enamel cannot be assessed and the diagnosis of very early stages of lesions affecting smooth surfaces is difficult, especially in primary teeth. Both factors may have resulted in an underestimation of grade 1 lesions on oral and vestibular surfaces.

However, erosive lesions in a more than incipient stage result in a significant substance loss with either clearly marked concavities or clearly visible changes in anatomical form, both of which can be easily diagnosed even on study models (13). In clinical indices the criterion of the amount of dentin exposed is a key factor which, of course, is not available in the diagnosis of study models. However, in the author's opinion, the exposure of dentin is merely a qualitative (e.g. regarding the prognosis of erosion progression) rather than a quantitative criterion and in many cases does not correspond with the true total substance loss. In areas where the covering enamel is thin, for example in the cervical region, even small erosive lesions often exhibit single spots of exposed dentin, whereas, on the other hand, in some cases a significant substance loss occurs without exposing dentin. Thus, the criterion "dentin affected" could be questioned as a reliable criterion for the quantification of erosive substance loss and even for clinical assessments. In the present study, these aspects may have resulted in a shift towards grade 1 lesions compared to the abovementioned clinical criteria and this would have to be considered when comparing the results with clinical trials from the literature.

Regarding dental erosion in permanent and

primary teeth with similar periods in function, strikingly higher prevalence data were observed in the latter. It has been shown that primary enamel is less mineralized (14) with a lower degree of crystallite arrangement (15), contains more water (16) and has an increased permeability (17) compared to permanent enamel. Correspondingly, Amaechi et al. (18) found that *in vitro* erosion progression was 1.5 times more rapid in human primary than permanent enamel. Together with differences in pellicle formation on primary and permanent teeth (19), this might explain the high prevalence of erosive lesions in the primary dentition. Additionally, after an erosive attack, the microhardness of primary enamel seems to be significantly lower than that of permanent enamel (20), which might result in an increased susceptibility of eroded primary teeth to an additional mechanically caused substance loss due to abrasion or demastication.

Since, to the authors' knowledge, no other studies regarding dental erosion in particular in randomly selected children and adolescents have been published, surveys using indices for tooth wear in general have to be used by way of comparison. In a Swedish study evaluating wear in incisal and occlusal surfaces of children and young adults at age 3, 5, 10, 15 and 20 years, lesions were common in the primary as well as in the permanent dentition. Only 63% of the 3-year-olds and 19% of the 5-year-olds had no or slight wear (primary teeth); for the 10-, 15-, and 20-year-olds the corresponding data were 78%, 51% and 35% (permanent teeth) (21). For permanent teeth the results approximately coincided with our findings (88.4% of the subjects at a mean age of 11.4 years and 77.0% at a mean age of 15.8 years showed no signs of erosion).

Another study examining a total of 1035 14-year-old British schoolchildren (9) revealed a relatively high rate of tooth wear affecting dentin. Of these children, 30% had exposed dentin, mainly occurring, however, incisally. In the present study, the incisal surfaces were excluded because of severe diagnostic problems. The incisal area seemed to be too small and the differentiation between erosion and attrition too difficult to achieve reproducible results. Additionally, in preliminary studies, grooving, which is defined as a criterion for erosion (12), was a common observation in a minimal stage and it appeared to be ambiguous to differentiate between insignificant grooving and significant grooving as a diagnostic criterion for erosion. However, severe substance loss for occlusal surfaces of molars as described by Milosevic et al. (9) was not observed.

Since the comparison of the presented data with other surveys on the prevalence of dental erosion or tooth wear is, strictly speaking, inadmissible, only a rough integration into the results published up to date is possible. For Germany, only one prevalence study dealing with a small group of adults has been published (7), but from the present study it can be suggested that dental erosion is not a serious problem for dental health in adolescents at the present. This holds true if grade 1 lesions are interpreted as normal features of functioning teeth even at this early age. Grade 2 lesions at age 11 or 15 can be definitely classified as pathological, but such lesions were scarce (0.2% of subjects at a mean age of 11.4 years and 1.5% at a mean age of 15.8 years had at least one tooth with a grade 2 erosive lesion). However, it must be emphasized that the examined study population cannot be considered representative. Despite orthodontic treatment being covered by health insurance and therefore accessible to all socioeconomic groups, orthodontic patients may have special attitudes to their oral health and may therefore represent a selected group. Furthermore, the studied group consisted of inhabitants of a local rural district, which, of course, is not representative for Germany. Therefore, the presented results have to be interpreted accordingly.

Considering the relatively low prevalence data of dental erosion in the permanent dentition of adolescents, a full mouth recording of erosive lesions during a routine dental examination seems to be inadequate at this age. Therefore, the identification of "marker teeth" would be useful as a time saving screening procedure. Looking at the distribution of erosive lesions by tooth side and tooth group, the most affected surfaces appear to be the oral surfaces of the maxillary canines and incisors, the vestibular surfaces of the maxillary canines and incisors and of the mandibular premolars, and the occlusal surfaces of the mandibular first molars (3, 4, 7, 9), even if there are variations due to the etiology (22). In the present study, which assessed very young subjects, erosive lesions were strikingly frequent in the occlusal surfaces of the mandibular first molars with other tooth groups or tooth sides being less affected. In addition, the mandibular first molars showed the greatest increase in lesions during the longitudinal observation period of 5 years. Had only the occlusal surfaces of the mandibular first molars been assessed, at a mean ages of 11.4 years ($n=998$) 87% and 15.8 years ($n=265$) 93.5% of the subjects suffering from dental erosion

would have been identified. The mandibular first molars may therefore represent marker teeth for the onset of dental erosion. At older ages, however, the occlusal surfaces of other tooth groups as well as smooth surfaces seem to be increasingly affected (3, 4, 7). Therefore, further research is needed to elucidate the individual progression of erosion even under different etiological factors.

During the last two decades, a significant increase of dental erosion in the primary as well as in the permanent dentition has been observed. Regarding the etiology of dental erosion, this may be due to general health factors (e.g. an increase in eating disorders among adolescents) but is more likely due to changes of nutritional behaviour. The erosive potential of soft drinks and fruits (23–26) as well as the association between the intake of acidic food and beverages and dental erosion is well established (4, 5, 7, 12, 27). In Germany, the intake of fruit and acidic beverages per capita has significantly increased during the last two decades. In the 1980s, the mean intake of fruit was 85 kg and of citrus fruit 30 kg per person compared to 93 and 32 kg in the 1990s. The consumption of soft drinks increased markedly from 71 to 91 liters per person and the consumption of fruit juice increased from 24 to 40 liters/per person (Bundesverband für Ernährung, Landwirtschaft und Forsten, written personal communication). In particular, the intake of cola-type drinks increased from 28 to 37 liters/per person (Bundesverband der Deutschen Erfrischungsgetränke-Industrie e.V., written personal communication). These remarkable data may explain the simultaneous increase in erosive lesions during the last two decades. Since most people are not aware of the potentially damaging effects of fruit, fruit juice and soft drinks, a nutritional consultation should not only include the recommendation to reduce the intake of cariogenic food but should provide sufficient information about a sensible consumption of acidic food.

However, in many cases there is no simple relationship between risk factors (e.g. the intake of acidic beverages) and the frequency and severity of erosive lesions (7, 28). Therefore, an individual predisposition depending on factors such as quantity and quality of saliva or composition of enamel and dentin must be supposed. Against this background, the question arises whether dental erosion occurring in the primary dentition can be a predictor for an increased risk for erosion in the permanent dentition. The longitudinal observation over a 5-year period revealed a significantly higher

prevalence of dental erosion in the permanent dentition if erosion had already been present in the primary teeth. Considering the young age, the low prevalence of erosive lesions in the permanent dentition as well as the changes in lifestyle reaching puberty, this was a surprising finding. However, the relative risk of 3.9 to develop erosive lesions in the permanent teeth if erosion was present in the primary dentition should not only motivate the inspection of primary teeth as a temporary phenomenon but they should be regarded as possible “predictor teeth”, providing early information about erosion and allowing prophylactic measures to be instituted.

The results of the present study indicate that dental erosion is a significant, but not a serious, problem for general dental health in adolescents in Germany at the present. However, the increasing prevalence data during the last two decades call for further cross-sectional and longitudinal prevalence studies. Furthermore, dentists’ awareness of dental erosion should be enhanced to allow early diagnosis and preventive measures.

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