

Maxillary incisor palatal erosion: no correlation with dietary variables?

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The objectives of the study were to examine a relationship between tooth erosion affecting the palatal aspects of permanent maxillary central incisors with dietary, behavioral and medical variables. The methods included, 251 schoolchildren aged 11 to 13 years were recruited to participate. Each subject had dental impressions of the palatal aspects of both upper central incisors recorded at baseline, 9 and 18 months intervals. From these, electroconductive replicas were fabricated, mapped and compared using a surface matching technique. At the end of the study all participants underwent a structured interview that sought to assay the level of potential erosive dietary, behavioral and medical risk factors. Correlation analyses of the responses given in the final structured interview with the degrees of palatal tooth substance loss (both previous and measured) were under taken. The results showed: 1. The degree of previous erosion did not predict the level of measured ongoing erosion. 2. Brushing the teeth more frequently with fluoridated toothpaste correlated significantly with lower levels of ongoing erosion ($P = 0.011$). It was concluded that: 1. Evidence of previous palatal erosion did not predict future erosion. 2. The application of topical fluoride as a by-product of tooth brushing may provide an element of protection against palatal erosion. 3. In view of the lack of correlation between exposure to potential risk factors and the level of ongoing palatal tooth surface loss in this study, other factors (such as an individual's susceptibility and salivary buffering power) may well be more important predictors. The clinical relevance included: Preventive advice to patients with dental erosion should not only include the use of topical fluoride, in the form of toothpaste, but recognize individual susceptibility to this condition.

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INTRODUCTION

The 1993 National Survey of Child Dental Health in the United Kingdom,¹ together with the more recent National Diet and Nutrition Survey² revealed a high prevalence of tooth surface loss due to

erosion. Like dental caries erosion, if unchecked, results in severe tooth destruction necessitating costly and time-consuming dental treatment and continual monitoring³ throughout life. Both dental caries and erosion arise from the destruction of mineralized tooth tissues by acid.

Unlike dental caries however, erosion results from direct acid contact with the teeth and no acid production by the oral microflora is involved. This acid may derive from dietary intake, medication, regurgitation of stomach contents or prolonged exposure to an acidic external environment.⁴ The precise relationship between acidic risk factors and the erosive process is, however, unclear for their effects may be modified by both biological (e.g. saliva - composition and flow rate, tooth composition and structure) and behavioral factors (e.g. unusual oral hygiene practices, dieting, eating, drinking and swallowing habits).⁵ In addition, *in vivo* research in this area has been severely handicapped by the lack of a sensitive quantitative technique to measure both the level and rate of progression of erosion. Although a variety of subjective ranking scales have been

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developed to assess toothwear,^{6,9} they are insufficiently sensitive to detect small changes in surface topography that may be of assistance in establishing *in vivo* erosion risk factors. It is a widely held belief that the increased consumption of acidic foods and beverages may account for the apparent increased prevalence of dental erosion, but the literature is inconclusive on a causative relationship. Such evidence is founded upon clinical trials, epidemiological studies, case reports and experimental clinical studies many of which are reviewed elsewhere.⁵ Due to the problems of measuring wear, notably due to the lack of fixed intraoral reference points, these have relied upon a variety of subjective ranking scales to assess the severity of wear. Previous work has also tended to adopt a whole mouth approach to the presence or absence of erosion rather than linking its presence at specific sites to potential risk factors. Using whole mouth models some studies have failed to find a causal relationship between such risk factors and erosion,^{2,10,11} whereas others¹²⁻¹⁴ have demonstrated one. Although the study of Milosevic, Lennon and Fear¹⁵ is often cited in the literature as demonstrating a causal relationship between erosion and the consumption of carbonated beverages it in fact did not do so, reporting a P value of 0.055 that fell just short of conventional statistical significance.

It was the aim of this work to examine a relationship between tooth erosion affecting specifically the palatal aspects of permanent maxillary central incisors, and dietary, behavioral and medical variables (as determined by structured interview), in a population of 251 school children aged 11 to 13 years. The study employed a previously developed quantitative wear assessment¹⁶⁻²⁰ that entailed recording addition silicone impressions of the dentition at baseline and at intervals thereafter, for the purpose of fabricating replicas for measurement and comparison by means of an electrical probe and a Surface Matching and Difference Detection Algorithm (SMADDA). It was hoped that the increased sensitivity afforded by such an approach would improve upon the robustness of the wear assessment over subjective ranking scales based upon a visual clinical examination, and also provide more stringent data on the dietary risk factors for palatal erosion of the maxillary permanent central incisors. In doing this work the authors acknowledge that a proportion of the palatal tooth surface loss will arise from the normal physiological processes of abrasion and attrition.

METHODS AND MATERIALS

This was a longitudinal observational study that sought to examine a relationship between tooth erosion affecting the palatal aspects of permanent maxillary central incisors and dietary, behavioral and medical variables (determined by structured interview), in a population of 251 school children aged 11 to 13 years. These were

recruited from pupils of four non-selective secondary schools (Arbroath High School, Camoustie High School, Monifieth High School and Montrose Academy in Scotland, UK) attending the Community Dental Service Schools screening program.

The quantitative assessment of palatal erosion employed a novel surface mapping and matching technique which had undergone a rigorous reliability assessment before its application to the measurement of the clinical replicas of this study. Risk factors (Dietary, Medical and Behavioral) were assessed by means of a standardized, structured interview.

Subject consent and recruitment In order to ensure informed written consent both guardian and child subject were issued with local ethical committee approved information sheets about the study prior to commencement. This permitted a period of reflection and discussion so that an individual was well aware of what participation in the study entailed. Following this time a total of 251 subjects consented to participate.

Data acquisition (Tooth morphology) An upper full arch impression of each participant was recorded in alginate using a stock tray. From this, a dental study cast was fabricated in dental stone upon which a sectional customized upper acrylic palatal surface impression tray was fabricated. This was of such a size as to cover the palatal surfaces of both the permanent maxillary central and lateral incisors. The tray was used subsequently to obtain detailed impressions of the palatal aspects of the central incisors at baseline, 9 and 18 months thereafter. All baseline and 18 month replicas were categorized as to the level of erosion affecting the tooth surfaces using criteria derived from the Ryge criteria for evaluating the quality of dental restorations.²¹ (Table 1) by two examiners (RGC and SLM) to consensus who, at the time of undertaking this task, were blind as to the results of the structured risk factor interview. These criteria had been shown previously to be well suited for the evaluation of tooth surface loss.^{8,9} Before obtaining the detailed impressions the palatal surfaces of the permanent maxillary central incisors underwent prophylaxis using a rubber cup and toothpaste to remove any tenacious surface debris. Residual traces of toothpaste were eradicated using a triple syringe before the impression was recorded finally in the customized tray, to which tray adhesive (Universal Adhesive, Coltene, Switzerland) had been applied according to the instructions, of the manufacturer using an addition cured silicone impression material of low viscosity (President, Coltene, Switzerland). Upon removal this was inspected for surface artifacts and if any were found, the impression was rejected and retaken. All satisfactory impressions were sent to the Dental School for re-inspection, replica fabrication and measurement.

The surface of each satisfactory impression was painted with a silver paint (RS Silver Paint, RS

Table 1. The Ryge derived criteria used to categorize the severity of erosion at baseline and 18 months.

Category	Criterion
R	No visible wear/change in anatomic form
S	Limited (normal) wear; limited change of anatomical form
M	Considerable wear; obvious change in anatomical form but no need for treatment
T	Considerable wear plus marked changes in anatomical form; further damage to tooth and/or surrounding tissues likely.
V	Excessive wear; extreme change in anatomical form, aesthetics and function; pain on chewing; damage to tooth and surrounding tissues.

Components, UK) applied using a brush. Once dry a further coat of paint was applied and two hours later, a layer of a cyanoacrylate based gel material (Zapit®, Dental Ventures of America Inc., USA) was applied to back up the painted surface and reinforce it. This was chemically hardened according to the instructions of the manufacturer. In order to facilitate both handling and mounting upon the mapping device, the thickness of the replica was increased by further backing up with die stone (Miles Dental Products, South Bend, IN, USA) mixed according to the manufacturer's recommended powder : liquid ratio, before being removed from the impression. Thus, upon removal from the impression, an electroconductive replica resulted whose surface was composed of a layer of silver paint conforming to the surface dimensions of the tooth under investigation as captured by the impression.

Each replica was transferred to the dedicated mapping device developed from that described by Chadwick *et al.*¹⁶ It was manufactured specifically for this project by the Medical Physics Department of Ninewells Hospital, Dundee, UK to BS EN ISO 9001 (22) and consisted of a precision x, y table (Daedal, Pittsburgh, USA), motorized by the addition of two computer controlled stepper motors (RS Components Ltd., Corby, UK) that controlled precisely the position of the table in the horizontal x, y planes. In addition, a third geared stepper motor under computer control, mounted perpendicular to the motorized table, governed the position of an electrical probe relative to the specimen. The probe was manufactured from tungsten carbide wire of 125 µm diameter (dark Electromedical, Pangbourne UK) and formed part of a feedback loop such that on coming into close proximity with an electrically conductive specimen, wired into the specimen chamber on the x, y table, it ceased its downward travel in the z direction and retracted 50 µm before moving on to the next measurement point.

Table 2. The criteria used to categorize the severity of wear as indicated on color coded surface difference plots generated by the quantitative wear analysis.

Category	Criteria
1	Majority of surface unchanged with 5 % or less exhibiting tooth surface loss.
2	Majority of surface unchanged with 6 - 15 % exhibiting tooth surface loss.
3	Majority of surface unchanged with 16 - 25 % exhibiting tooth surface loss.
4	26 - 50 % of the surface exhibits tooth surface loss.
5	51 % or greater of the surface exhibits tooth surface loss.

Table 3. Summary of potential erosive risk factors as assayed by structural interview.

Medical and Medical Conditions

- Hiatus hernia, achlorhydria, eating disorder, asthma, medication

Behavioral

- Time at which eating/drinking commences on rising
- Most common method of drinking
- Bedtime (including if drink before going and what is drunk)
- Tooth brushing frequency with times in relation to meals and last brush at night
- Use of fluoride toothpaste or mouthrinse
- Changes in eating/drinking patterns over the period of the study

Dietary

- Special diets, including vegetarian
- Quantity and frequency of intake of potentially erosive beverages, e.g. fruit juice, flavored fizzy drinks, sports drinks, herbal teas, drinks with alcohol, fizzy water, salad creams, dressings or vinegar, yogurts, named fruits

All such data was computer logged and, to minimize the effects of backlash in the stepper motors, measurement was only undertaken when the stepper motors were driving the stage in the positive x and y directions. The positioning and measurement resolution in the x, y and z planes was ± 2.5 µm. Throughout this work, the x and y intervals at which the elevation (z co-ordinate) of the replica was determined, were set at 150µm. To allow rapid mapping of the replicas two such machines were used for the project and, although both complied with the above specification, further potential measurement errors were minimized, by allocating each subject to a particular machine. There was thus no interchanging of measurement device for a subject throughout the study.

The resultant data files for each replica type, comprising a series of Digital Terrain Models (DTM's) consisting of many x, y and z-co-ordinates (generally

around 50 x 50 points in size (150µm apart) giving 2,500 data points in all within a grid of 7.5 mm x 7.5 mm) for each replica were then compared using a Surface Matching and Difference Detection Algorithm (SMADDA). This utilized a least squares approach to surface matching in which the surfaces being compared were moved mathematically so that the surface of one DTM was superimposed upon that of another for comparative purposes. Full accounts of the mathematics involved in this procedure are given in Mitchell and Chadwick.^{23,24} For each subject completing the study a total of 4 surface matches were conducted (i.e. for each central incisor, matches of baseline versus 9 month and 18 month replicas). Any detected change in surface morphology was expressed both numerically and in the form of a color coded surface plot,²⁵ which was generated using the 3D contouring and mapping software package Surfer (Version 6, Golden Software Inc., Colorado, USA). In order to rationalize this complex numerical output for epidemiological purposes, each plot was inspected and classified according to a 5 point scale (Table 2) specifically developed for this project.²⁶

This was undertaken to distinguish between tooth surfaces with apparently identical numerical volumes of surface loss yet completely different anatomical distributions. For example, a tooth displaying multiple regions of depth loss was distinguished, by the use of this scale, from a tooth with a single localized area of erosion, even though the total volume change was the same. Multiple regions of depth loss are of greater clinical significance and the use of the ranking scale, based upon numerical data, allows such an occurrence to be given greater weighting.

Data acquisition (Dietary and other risk factor identification) At the 18 month final recall, all subjects underwent a standardized structured interview that sought to assay the level of potential erosive risk factors as summarized in Table 3. These had previously been identified by a search of the scientific literature.

Data Processing and Analysis The details of the structured interviews and erosion assessments for each participant were entered into the project database (Paradox 3.5, Borland International, CA 95067-0001, USA) customized for use in this project. This was interrogated in order to export data to permit statistical analyses to be undertaken.

Correlation analyses were undertaken of the degree of erosion observed at the start of the study (as determined by ranking using the Ryge system (Table 1)) and ongoing erosion (measured using the SMADDA during the study) versus the risk factors (Table 3) as quantified using the structured interview.

All correlation analyses were undertaken using the statistical package SPSS-X (Version 9.0, SPSS Inc., 233 S. Wacker Drive, Chicago, Illinois 60606, USA).

RESULTS

A total of 250 schoolchildren were recruited to participate in this study. Of these 197 (93 males and 104 females) completed the study giving a drop out rate of approximately 21%.

The degree of palatal erosion observed at baseline, as classified using the Ryge derived Criteria (Table 1), was within normal clinical limits for 58.5 % (n = 113 subjects) of the sample (Categories R and S); in excess of the norm, but not requiring treatment for 28.7% (n = 55 subjects) (Category M); and of such an extent as to suggest that treatment of the condition was required in 12.3% (Categories T and V) (n = 24 subjects). Upon completion of the study the Ryge derived criteria did not detect any deterioration in palatal morphology with the exception of two teeth, in two subjects, where there was a shift from Category S to M.

Due to a combination of the unsuitability of a number of impressions for replication and subject absences at one of the recall intervals, a total of 265 teeth out of a possible 394, underwent quantitative analysis of ongoing wear using the SMADDA. Of these over the study period, the number of teeth undergoing surface loss was 38, of which 21 exhibited a change of Category 1 - 2, 14 a change of category 1 - 3, 2 a change of category 1 to 4 and one a change in category 1-5 (for categories see Table 2).

One hundred and ninety four (194) subjects said they used fluoride toothpaste and two claimed not to use it. Only 48 subjects used a fluoride mouth rinse.

Correlation analyses undertaken of the degree of erosion observed at the start of the study (as determined by ranking using the Ryge system (Table 1)) and ongoing erosion measured using the SMADDA during the study versus the risk factors quantified using the structured interview, demonstrated only two statistically significant correlations and both were negative: Brushing the teeth more frequently correlated significantly with lower levels of ongoing erosion ($P = 0.011$, Spearman Correlation Coefficient = -0.192).

The degree of previous erosion, as determined by the Ryge system at the start of the study, was significantly correlated with the frequency of fizzy water intake ($P < 0.01$, Spearman Correlation Coefficient = -0.600).

There were no correlations of statistical significance between the degree of previous erosion (as determined by the Ryge system) and the levels of ongoing erosion (as determined at 9 and 18 months using the SMADDA) for either the upper left or right central incisor as summarized in Table 5.

DISCUSSION

This study is unique for it has focused, as intended, specifically on the degree of palatal erosion affecting the upper central incisors. It has also employed a novel method of assessing palatal tooth surface loss in an

Table 4. Spearman's Rank Correlation and Significance Levels for Risk Factors versus Ongoing Erosion (as measured) and Previous Erosion (as determined by Ryge Ranking).

RISK FACTOR	ONGOING EROSION		PREVIOUS EROSION	
	Spearman r	P	Spearman r	P
Time of commencement of Eating/Drinking	.023	.762	.051	.492
Bedtime	-.018	.810	-.028	.703
Bedtime Drink	.081	.283	-.066	.365
Toothbrushing frequency	.192	.011*	-.009	.902
Eat/Drink after brushing	.093	.217	.021	.771
Brush before/after meals	.057	.452	-.015	.842
Use of Fluoridated Toothpaste	.095	.207	-.015	.835
Dietary – frequency of intake	.007	.923	-.038	.600
Fruit Juice	.081	.326	.017	.828
Flavored Fizzy drinks	-.095	.262	-.057	.484
Sports Drinks	-.025	.889	.023	.894
Herbal Teas	-.359	.343	-.014	.970
Alcohol	-.424	.402	-.432	.212
Fizzy Water	-.027	.894	-.600	.000**
Yogurt	-.051	.661	-.015	.897
Fruit	-.150	.135	-.029	.765

endeavor to reduce the level of subjectivity that inevitably arises when applying subjective erosive ranking scales based upon a visual examination (as used in previous studies) and to increase the sensitivity of detection. The replication and surface mapping components of the quantitative system used in this study have been shown to accurately quantify wear to ± 4.4 μm (S.D. = 2.8) (16) and have high reproducibility.^{18,19} In addition, the SMADDA has been shown capable of quantifying dental erosion^{17,23,24} giving a root mean square error, from matching a series of measurements of a repeatedly measured replica, of 10 μm .²⁰ The technique has therefore been shown to be accurate, reproducible and fit for purpose.

As well as assessing ongoing erosion by means of measurement, the present study has also taken into account the presence of any previous palatal erosive tooth surface loss of the palatal aspect of the maxillary central incisors, by means of criteria derived from the Ryge criteria for evaluating the quality of dental restorations.²¹ This scale is based upon operational criteria and has been shown to be well suited to the evaluation of tooth surface loss.^{8,9} Their use also permitted the investigators to see if the application of the quantitative SMADDA technique discerned any

Table 5. Summary of correlation of the degree of previous erosion and the measurement levels of ongoing erosion at 9 and 18 months for the upper left and right central incisors.

Upper left central incisor		
	9 months	18 months
Spearman r	0.009	0.162
95% confidence intervals	-0.164 to 0.180	-0.007 to 0.321
P	0.920	0.053
Upper right central incisor		
	9 months	18 months
Spearman r	0.033	0.079
95% confidence intervals	-0.138 to 0.202	-0.088 to 0.242
P	0.696	0.338

changes in surface topography that were missed by such a conventional subjective ranking. The quantitative method did indeed pick up changes in surface topography that were missed by the Ryge derived ranking scale.

In common with a number of other workers, we did not demonstrate a causal relationship between acidic risk factors and erosion,^{2,10,11} whereas others have.¹²⁻¹⁴ The situation reported here, however, differs from those of these workers for we did not adopt a whole

mouth approach, but focused specifically upon the palatal aspect of permanent maxillary central incisors.

Indeed, in relation to palatal erosion our finding of no dietary correlation would appear to sit well with the reports of Linnett *et al.*,²⁷ (in children) and Lussi, Jaeggi and Schaffner,²⁸ (in adults), who both considered gastro-oesophageal disease to be a more significant etiological factor than has previously been thought,²⁷ and that chronic vomiting appeared to be a more decisive factor for palatal tooth surface loss than diet.²⁸

Despite finding no dietary correlation for ongoing erosion we did demonstrate an apparent protective effect against erosion conferred by toothbrushing. As the abrasive action of brushing can accelerate the loss of tooth substance exposed to acids²⁹ an explanation of this finding is indicated.

The majority of our subjects used fluoride toothpaste and this is known to promote remineralization of tooth substance following an acidic challenge.³⁰ Observational studies on toothbrushing in both adults and children, show that the palatal surfaces of upper incisor teeth may be less frequently brushed than other tooth surfaces in the oral cavity.^{31,32} It would seem reasonable to hypothesize that brushing, for the subjects in this study, provides a vehicle for topical fluoride application that promotes remineralization and protects against erosion.

Although we successfully detected and monitored ongoing erosion over an 18 month period in a number of subjects, it would appear to be a phasic or discontinuous process as many more of the subjects demonstrated previous signs of erosion at the start of the study as assessed by the Ryge derived system. Furthermore, the fact that there was little difference in the Ryge ratings at 18 months indicates the enhanced sensitivity such a quantitative approach brings.

In relation to previous erosion we demonstrated a significant protective effect of the consumption of fizzy (mineral) water. This finding would agree well with the *in vitro* observations of Parry *et al.*,³³ who postulated that the complex and heterogeneous mineral compositions of mineral waters could influence the dissolution equilibrium of apatite in enamel reducing its dissolution on exposure to acid. Another possible explanation would be that those who consumed fizzy mineral waters consumed significantly less other types of carbonated beverages, but statistical analysis of our data did not support this alternative explanation.

Finally, the absence of a correlation between exposure to the potential risk factors drawn from the literature and the level of ongoing palatal erosion observed (with the exception of toothbrushing) suggests that other factors and the interaction may well be more important, such as an individual's susceptibility and salivary buffering power. As suggested by others,³⁴ further work to develop a more comprehensive model is required if we are not to make naive assumptions

about the cause of dental erosion and thus hinder our efforts at effective maintenance and prevention.

CONCLUSIONS

For the subjects, teeth and period of this study:

- Evidence of previous palatal erosion does not predict future erosion perhaps due to the episodic nature of the condition.
- The application of topical fluoride as a by-product of toothbrushing may provide an element of protection against palatal erosion.
- There was no correlation between exposure to potential risk factors and the level of ongoing palatal erosion observed, with the exception of toothbrushing. This suggests other factors may well be more important, such as susceptibility of the individual and salivary buffering power.
- The consumption of fizzy (mineral) water conferred a significant protective effect against palatal erosion.

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