Oral Clearance of an Acidic Drink in Patients with Erosive Tooth Wear Compared with That in Control Subjects

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Purpose: The aim of this study was to compare the clearance of an acidic drink in patients with tooth wear caused by regurgitation erosion to that in patients without tooth wear. **Materials and Methods:** Oral clearance was measured using antimony electrodes at 4 soft tissue sites around the mouth in the patients with erosion caused by regurgitation and compared to a matched control group. The data were analyzed for pH at the resting state, the time below 5.5, and the lowest recorded pH. In addition, the resting hydration levels and viscosity of fluid from the minor salivary glands, the pH of resting saliva, and the flow rate and buffering capacity of stimulated saliva were compared between the 2 groups of patients. **Results:** The pH recorded at the tip of the tongue reached a lower level in the controls than in those in the erosive tooth wear group ($P < .05$) and the time that the pH remained below 5.5 was longer in the controls than those with tooth wear ($P < .05$). The flow rate from the minor salivary glands ($P < .05$) and the viscosity of resting saliva appeared to differ between the two groups ($P < .001$). **Conclusion:** Oral clearance at the tip of the tongue, measured as a function of the lowest pH reached and the time below 5.5, was quicker in those with erosive tooth wear than the controls. It is suggested that this may be a result of a feedback mechanism from constant exposure of the oral environment to low pH. *Int J Prosthodont 2005;18:323–327.*

The term *erosion* describes the process of gradual destruction of teeth by chemical processes.[1] The most common causes of erosion are dietary and gastric acids; erosion resulting from atmospheric exposure to industrial acids is rare. Several studies have shown that excessive consumption of orange and lemon juices can erode enamel.[2–4] The amount of mineral dissolved from enamel depends on 2 main factors: the type of acid and host factors. In cases of erosive tooth wear caused by dietary acid intake, the important characteristics of the acid include pH, pKa, and titratable acidity.[5] Host factors include frequency and timing of the acid intake, proximity of the tooth to salivary ducts, and nature and flow rate of saliva; the consequent duration of low pH will influence the potential for erosion to occur.[6]

Regurgitation of gastric juice into the mouth is known to cause dental erosion.[7–10] Gastric juice in patients with gastroesophageal reflux disease passes through the upper and lower esophageal sphincters to reach the mouth, where it causes erosion. Typically, the site of erosion most commonly affected is the palatal surfaces of the maxillary anterior teeth, although in chronic and long-standing disease, the effect is more generalized.

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The anatomy of soft tissues around the teeth and physiological soft tissue movements influence the tooth site that acids contact and also affects the clearance pattern of acidic substances from the mouth.[11] Millward et al monitored pH at the surface of teeth of healthy volunteers after drinking 1% citric acid.[12] They observed that the pH recovered to above 5.5 within 2 minutes at a site adjacent to the palatal surfaces of the maxillary central incisors and within 4 to 5 minutes at the maxillary first molars.

Salivary buffers are the main protectors against tooth erosion, and some studies have associated low salivary buffering capacity with tooth erosion.[13–15] A low salivary flow rate has also been suggested as a contributor to erosion.[16] Salivary flow rates increase within 1 minute after drinking acidic soft drinks, from 0.15 mL/min at rest to around 1.5 mL/min. Usually, flow rates return to a normal resting level within 6 minutes. Consequently, a pH below 5.5 lasts less than 5 minutes at the enamel surface in the absence of plaque.[12]

The palatal surfaces of the maxillary incisors and the occlusal surfaces of molars are common sites for erosive tooth wear[17] and clearance of acid in these areas might be important. Since it is impossible to monitor the clearance of stomach acid under controlled conditions, the aim of this study was to compare oral clearance of an acidic drink in patients with erosion caused by regurgitation with that of a control group of patients without erosive tooth wear. The null hypothesis was that the clearance rate and salivary parameters of both groups would not differ.

Methods and Materials

Subjects

Subjects were recruited from patients attending Guy's Dental Hospital (London) for dental treatment. Subjects were recruited if they were otherwise medically fit and healthy and not on medication. After being informed about the investigation, 20 subjects agreed to participate in the study, and all provided prior written consent. No patients had removable dentures or orthodontic appliances. Those subjects selected for the erosion group had been referred for restorative management of erosive tooth wear caused by regurgitation and had at least two thirds of the dentin exposed on the palatal surfaces of the maxillary incisors. These subjects had undergone 24-hour pH testing and had been diagnosed with gastroesophageal reflux using internationally agreed guidelines.[18]

Control subjects were recruited from patients presenting to the hospital without erosive tooth wear and not complaining of symptoms of reflux. A tooth wear index was recorded on each subject using the classification of Smith and Knight.[19] The teeth were thoroughly dried and each tooth was graded by a single operator from 0 to 4 based on the severity of tooth wear. No control had a tooth wear score above 2 on any tooth surface.

pH and Titratable Acidity of the Drinks

The pH of a 50-mL sample of freshly opened orange juice and a still water drink, warmed to room temperature (19°C), was measured with a pH211 Microprocessor pH Meter (HANNA Instruments). The pH readings were repeated 3 times for both drinks to give a mean value. To assess the titratable acidity, a 50-mL sample of each drink was titrated with 1 mol/L sodium hydroxide, added in 10-µL increments to still water and 100-µL increments to orange juice until the pH reached 7.[20] Titrations were repeated 5 times for both drinks to ensure reproducibility and to give a mean value for the drink.

Saliva Measurements

All clinical measurements were undertaken at the same time of day (midday) to avoid diurnal variation. Subjects refrained from drinking or eating 3 hours prior to the experiment. The study used a GC Saliva-Check Kit (GC Corporation) to analyze the "resting hydration rate" and viscosity of fluid from the minor salivary glands using a visual examination. In addition, the kit measured the pH of resting saliva and the flow rate and buffering capacity of stimulated saliva. The resting hydration rate of the minor salivary glands was measured by recording the time for saliva to be produced on the lower labial mucosa, midway between the vermilion border and the attachment of the lower lip to the labial frenum. The lower lip was inverted and gently dried with a small piece of gauze and the mucosa was observed under good light. The viscosity of this saliva was assessed with good lighting and categorized according to Table 1.

Subsequently, the patients avoided swallowing for 30 seconds. The pooled saliva formed in the mouth was collected in a cup and the pH measured using a pH test strip. The patient was then instructed to chew a piece of paraffin wax to stimulate salivary flow. After 30 seconds the saliva was expectorated and discarded. Subjects continued chewing for 5 more minutes, and the saliva was collected in the cup every 15 seconds. The quantity of saliva was measured, and the buffering capacity was measured immediately using a test strip.

pH Measurement

The antimony-pH electrode (Medtronic, A/S), originally used for monitoring esophageal and gastric pH, was calibrated according to the manufacturer's instructions. The 1-mm-square electrode was held at the end of a catheter and connected to a data logger (Oakfield). A 50-mL sample from a freshly opened still water drink, at room temperature, was given to each subject. Subjects were asked to swirl it around in the mouth for 45 seconds and then drink it. The pH was then measured in the same order at 4 sites: the tip of the tongue, the dorsum of the tongue, the buccal mucosa opposing the mandibular right molar, and the labial mucosa opposing the maxillary incisors. Each pH measurement took 7 seconds. Following the 4 measurements, a 30-second interval was provided. The pH measurement procedure was repeated 5 times with this interval, and then the interval between measurements was increased to 2.5 minutes. This procedure was repeated 7 times or until pH returned to the resting pH. The subjects were given 30 minutes rest before the rinsing and pH measurement procedure was repeated with orange juice. The length of time that the pH remained below 5.5 was recorded for each subject after both drinks, together with the lowest pH reached.

Statistical Analysis

The data were derived from relatively small samples ,and in many cases, were not normally distributed; thus, a nonparametric approach was used. The Mann-Whitney *U* test was performed to analyze differences between the erosive tooth wear group and the control group. The Chi-square test was used to compare the viscosity of saliva. The significance level chosen in all statistical tests was .05.

Results

Ten subjects (5 men and 5 women), were recruited to each group. The mean age was 43.7 years (SD 14.06) in the erosive tooth wear group and 40.9 years (SD 10.38) in the control group. All subjects successfully completed the study. The pH and titratable acidity of the orange juice were 3.8 and 7.2 mL respectively, and the pH of the still mineral water was 7.9.

Table 2 shows that the initial pH recording obtained from each site was approximately neutral. Table 3 shows the median duration in minutes for the time that the pH remained below 5.5 on the tip of the tongue, the dorsum of the tongue, and the buccal mucosa adjacent to the mandibular molars and maxillary incisors. There were statistically significant differences between the 2 groups for the time below pH 5.5 on the tip of the tongue ($P = .028$). Table 4 shows the median for the lowest pH reached at the 4 sites for the controls and erosive tooth wear groups. Subjects without erosion had statistically significantly lower pH on the tip of the tongue and on the buccal mucosa adjacent to the mandibular molars ($P = .006$ and .044, respectively).

Table 1 Viscosity Index for Resting Fluid from the Minor Salivary Glands

Visual observation	Implied viscosity
Watery, clear	Normal
Frothy, bubbly	Increased
Sticky, frothy, residues	Very high

Table 5 shows the median for saliva parameters for the erosive tooth wear and control groups. The erosive tooth wear group took around 30 seconds longer to produce saliva from the minor labial glands than the controls, and this difference reached statistical significance ($P = .013$). There were no statistical differences between the groups for pH of resting pooled saliva or the flow rate or buffering capacity of stimulated saliva. Eight subjects in the erosive tooth wear group showed increased viscosity of the fluid from the minor salivary glands, whereas this was observed in only 2 control subjects ($P = .007$).

Discussion

The number of subjects in the present study was small but similar to previous studies, both of which used 20 subjects.[21,22] The proportion of men to women in this study was equal in both groups, and there were no statistical differences between the groups in age. Both factors have been shown to be relevant to saliva and erosive tooth wear.[23–25]

In this investigation, pH measurements were used to assess oral clearance of an acidic drink. A similar method using antimony electrodes to measure plaque pH was reported by Kleinberg and Jenkins.[26] The small antimony electrode was useful, practical, and easily located at the same mucosal area on each patient.

The underlying cause of the erosive tooth wear in the subjects in this study was regurgitation of gastric contents into the mouth. The association between gastroesophageal reflux and dental erosion has been previously established.[7] Ideally, it would have been more relevant to test the oral clearance of gastric acid; however, this would not have been ethical or practically possible. Undoubtedly, there are differences in the pH, viscosity, and the consequent oral clearance of dietary and gastric acids.

It has been suggested that the salivary parameters of patients with erosive tooth wear caused by regurgitation might be innately different or altered by the condition. In the present investigation, resting saliva hydration (estimated from production of fluid from the lower labial glands) was significantly faster in controls than in the erosive tooth wear patients. This flow can-

Table 2 Median (Interquartle Range) Resting pH at Four Soft Tissue Sites for Patients with Erosive Tooth Wear and Controls

	Site		
Resting pH	Patients	Controls	*P* value
Tip of the tongue	7.50 (7.2–8.0)	7.75 (7.6–7.8)	.542
Dorsum of the tongue	7.85 (7.7–8.2)	8.20 (8.0–8.3)	.086
Buccal mucosa adjacent maxillary molars	7.70 (7.4–8.1)	7.45 (7.1–7.8)	.128
Labial mucosa opposing maxillary incisors	7.45 (7.2–7.9)	7.20 (6.8–7.5)	.120

Table 3 Median (Interquartle Range) Time (in Minutes) that pH Remained Below 5.5 at Four Soft Tissue Sites for Patients with Erosive Tooth Wear and Controls

	Site		
Time below pH 5. 5 (min)	Patients	Controls	*P* value
Tip of the tongue	0 (0–1)	1 (1–1)	.028
Dorsum of the tongue	1 (0–1)	1 (0–1)	.86
Buccal mucosa adjacent maxillary molars	0 (0–0)	0.5 (0–1)	.26
Labial mucosa opposing maxillary incisors	1 (0–2)	1 (1–4)	.67

Table 4 Median (Interquartle Range) of Lowest pH Recorded at Four Soft Tissue Sites for Patients with Erosive Tooth Wear and Controls

	Site		
Lowest pH	Patients	Controls	*P* value
Tip of the tongue	5.65 (4.9–6.0)	4.8 (4.1–5.4)	.006
Dorsum of the tongue	5.25 (5.2–5.6)	5.3 (4.7–5.5)	.59
Buccal mucosa adjacent maxillary molars	5.9 (5.5–6.2)	5.45 (5.3–5.7)	.044
Labial mucosa opposing maxillary incisors	5.25 (4.8–6.0)	5.15 (5.0–5.3)	.54

Table 5 Median (Interquartle Range) of the Salivary Factors in the Patients with Erosive Tooth Wear and Controls

	Patients	Controls	*P* value
Resting saliva hydration (s)	60 (30–89)	30 (25–37)	.013
pH	7.0 (6.6–7.2)	6.9 (6.8–7.2)	.97
Volume (mL)	7.5 (5.0–9.0)	8.25 (6.0–9.0)	.59
Buffering capacity	10.0 (8.0–11.0)	11.5 (10.0–12.0)	.23

not be equated with total resting saliva production since the minor salivary glands only produce about 10% of the total saliva.[27] The method to assess resting saliva hydration is convenient, but without further investigation it cannot be directly compared to conventional resting salivary flow.

Oral clearance of gastric acid would be expected to depend upon the flow rate and buffering capacity of both resting and stimulated saliva from all glands. However, no differences in the flow or buffering capacity of stimulated saliva were observed between the groups in the present study.

The viscosity of the fluid from the minor salivary glands was assessed visually and, like the resting saliva hydration rate, the technique was simple and subjective. In the erosive tooth wear group, the saliva consistency was generally more viscous than normal in contrast to the control group. The results indicate a difference in the constituents of this fluid from the 2 groups, which may be related to a higher protein concentration in patients in the erosive tooth wear group. More research is needed on this relatively new method of assessment.

The study of Moazzez et al reported that dietary acids were buffered to pH 7 within a few minutes.[6] The pH of gastric and dietary acids has been reported to be similar, but their titratable acidity is different, and therefore, the time needed to buffer gastric acids may be longer than dietary acids; this requires further investigation.[28] Despite the need to use a dietary acid to test oral clearance, the results showed differences in pH, particularly at the tip of the tongue, which suggests that patients with erosive tooth wear have more rapid oral clearance than patients without tooth wear. Other authors have previously reported the finding in long-term sufferers of gastroesophageal reflux, who appear to show increased salivary flow as part of a feedback mechanism.[29] Although no statistically significant differences were observed in the flow rate of saliva in the present study, it is suggested that patients who suffer from gastroesophageal reflux show improved oral clearance as the result of a feedback mechanism.

Conclusions

Patients with erosive tooth wear caused by regurgitation showed more rapid oral clearance than patients without tooth wear. It is suggested that this may be the result of a feedback mechanism from constant exposure of the oral environment to low pH. Minor differences in the quantity and quality of saliva would warrant further investigation.

References

1. Imfeld T. Dental erosion. Definition, classification and links. Eur J Oral Sci 1996;104:151–155.
2. Grobler SR, Senekal PJC, Laubscher JA. In vitro demineralisation of enamel by orange juice, apple juice, pepsi cola, and diet pepsi cola. Clin Preventive Dent 1990;12:5–9.
3. West NX, Maxwell A, Hughes JA, Parker DM, Newcombe RG, Addy M. A method to measure clinical erosion: The effect of orange juice consumption on erosion of enamel. J Dent 1998 May;26:329–335.
4. Stafne EC, Lovestedt SA. Dissolution of tooth substance by lemon juice, acid beverages and acids from other sources. J Am Dent Assoc 1947;34:586–592.
5. West NX, Hughes JA, Addy M. Erosion of dentine and enamel in vitro by dietary acids: the effect of temperature, acid character, concentration and exposure time. J Oral Rehabil 2000;27:875–880.
6. Moazzez M, Smith BGN, Bartlett DW. Oral pH and drinking habit during ingestion of a carbonated drink in a group of adolescents with dental erosion. J Dent 2000;28:395–397.
7. Bartlett DW, Evans DF, Anggiansah A, Smith BGN. A study of the association between gastro-oesophageal reflux and palatal dental erosion. Br Dent J 1996;181:125–131.
8. Chandra A, Moazzez R, Bartlett DW, Anggiansah A, Owen WJ. A review of the atypical manifestations of gastroesophageal reflux disease. Int J Clin Pract 2004;58:41–48.
9. Gregory-Head BL, Curtis DA, Kim L, Cello J. Evaluation of dental erosion in patients with gastroesophageal reflux disease. J Prosthet Dent 2000;83:675–680.
10. Schroeder PL, Filler SJ, Ramirez B, Lazarchik DA, Vaezi MF, Richter JE. Dental erosion and acid reflux disease. Ann Intern Med 1995;122:809–815.
11. Thomas AK. Further observations on the influence of citrus fruit juices on human teeth. N Y S Dent J 1957;23:424–430.
12. Millward A, Shaw L, Harrington E, Smith AJ. Continuous monitoring of salivary flow rate and pH at the surface of the dentition following consumption of acidic beverages. Caries Res 1997;31:44–49.
13. Linkosalo E, Markkanen H. Dental erosions in relation to lactovegetarian diet. Scand J Dent Res 1985;93:436–441.
14. Gudmundsson K, Kristleifsson G, Theodors A, Holbrook WP. Tooth erosion, gastroesophageal reflux, and salivary buffer capacity. Oral Surg Oral Med Oral Pathol 1995;79:185–189.
15. O'Sullivan EA, Curzon MEJ. Salivary factors affecting dental erosion in children. Caries Res 2000;34:82–87.
16. Milosevic A, Dawson LJ. Salivary factors in vomiting bulimics with and without pathological tooth wear. Caries Res 1996;30:361–366.
17. Bartlett DW, Coward PY, Nikkah C, Wilson RF. The prevalence of tooth wear in a cluster sample of adolescent schoolchildren and its relationship with potential explanatory factors. Br Dent J 1998;184:125–129.
18. Johnson LF, DeMeester TR. Twenty four hour pH monitoring of the distal esophagus. Am J Gastroenterol 1974;62:325–332.
19. Smith BGN, Knight JK. An index for measuring the wear of teeth. Br Dent J 1984;156:435–438.
20. Touyz LZ, Silove M. Increased acidity in frozen fruit juices and dental implications. ASDC J Dent Child 1993;60:223–225.
21. Anderson LA, Orchardson R. The effect of chewing bicarbonate-containing gum on salivary flow rate and pH in humans. Arch Oral Biol 2003;48:201–204.
22. Duggal MS, Tahmassebi JF, Pollard MA. Effect of addition of 0.103% citrate to a blackcurrant drink on plaque pH in vivo. Caries Res 1995;29:75–79.
23. Eliasson L, Birkhed D, Heyden G, Stromberg N. Studies on human minor salivary gland secretions using the Periotron method. Arch Oral Biol 1996;41:1179–1182.
24. Heintze U, Birkhed D, Bjorn H. Secretion rate and buffer effect of resting and stimulated whole saliva as a function of age and sex. Swed Dent J 1983;7:227–238.
25. Lussi A, Schaffner M, Holtz P, Suter P. Dental erosion in a population of Swiss adults. Community Dent Oral Epidemiol 1991;19:286–290.
26. Kleinberg I, Jenkins GN. The pH of dental plaques in the different areas of the mouth before and after meals and their relationship to the pH and rate of flow of resting saliva. Arch Oral Biol 1964;9:493–516.
27. Dawes C, Wood CM. The contribution of the oral minor mucous gland secretions to the volume of whole saliva in man. Arch Oral Biol 1973;18:337–342.
28. Bartlett DW, Coward PY. Comparison of erosive potential of gastric juice and a carbonated drink in vitro. J Oral Rehabil 2001;28:1045–1047.
29. Helm JF, Dodds WJ, Hogan WJ. Salivary response to esophageal acid in normal subjects and patients with reflux esophagitis. Gastroenterology 1987;93:1393–1397.