Caries experience in adolescents 13-14 years with and without erosive tooth wear: a case-control study

Alvaro Edgar González-Aragón Pineda*/ Alvaro García-Pérez**
/ José Francisco Gómez-Clavel***

Background: *Erosive tooth wear (ETW) and dental caries have common etiological factors, such as unhealthy eating habits, and reduced salivary flow rate.* ***Aim:*** *To analyze the association between caries experience (CE) and ETW in adolescents 13–14 years.* ***Study design:*** *Ninety-seven cases with distinctive ETW were identified and then sex-matched with a group of 97 controls and a group of 97 cases with initial ETW. The variables included were CE, presence of debris/dental calculus, salivary parameters, food and beverage consumption, chewable vitamin C tablet consumption, gastroesophageal reflux, frequent vomiting, and tooth brushing. Multinomial logistic regression models were adjusted.* ***Results:*** *An association was found between cases with a distinctive ETW defect and CE (OR = 1.09 (95% CI: 1.01–1.17); p = 0.020), sweet carbonated drinks consumption (OR = 1.16 (95% CI: 1.03–1.31); p = 0.012), and frequent vomiting (OR = 3.19 (95% CI: 1.02–10.01); p = 0.047).* ***Conclusions:*** *The preventive management of both ETW and dental caries should aim to reduce exposure to foods and beverages with high acid and sugar content. Given the association between ETW and acid attack by gastric juice, this would be an indicator of the need for referral to a specialist for treatment.*

Keywords: *Dental caries, Erosive tooth wear, Dental erosion, Adolescents*

INTRODUCTION

Dental caries is the localized destruction of hard dental tissue by the acidic by-products of the bacterial fermentation of free sugars [1]. Despite being largely preventable, dental caries is the most common oral disease in the world, with increasing prevalence in many low and middle-income countries [2]. The oral environment is a modifier of caries risk that influences tooth development (*e.g.*, fluoride exposure, risk of enamel defects), oral hygiene, topical fluoride exposure, carbohydrate exposure, microbiome exposure, and many other factors which also may modify the development of dental caries. On the other hand, the size, mineralization, and, even, morphology of pits and fissures are strongly determined by the genetic makeup or genome of the individual [3].

Tooth wear is the progressive loss of dental hard tissues through three processes. The first two are mechanical processes: abrasion (wear produced by interaction between teeth and other materials) and attrition (wear through tooth-tooth contact). These can contribute simultaneously to occlusal wear [4]. When the surface of the tooth is first attacked by acids, the resulting loss of structural integrity leaves a softened layer on the tooth's surface, which renders it vulnerable to mechanical processes. These mechanical processes forces will remove the softened layer on dental hard tissues, causing substance loss [5].

Erosive tooth wear is defined as a chemical-mechanical

From the Laboratory of Public Health Research, Faculty of Higher Studies (FES), Iztacala, National Autonomous University of Mexico (UNAM), Mexico.
*Alvaro Edgar González-Aragón Pineda, DDS, MSc, PhD.
**Alvaro García-Pérez, DDS, MSc, PhD.
***José Francisco Gómez-Clavel, DDS, PhD.

Corresponding Author:
Alvaro Edgar González-Aragón Pineda
Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México,
Avenida de los Barrios Número 1, Colonia Los Reyes Iztacala Tlalnepantla,
Estado de México, C.P. 54090 México.
Phone: 55-29546769
E-mail: alvaroedgar@unam.mx

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process that results in the cumulative loss of hard dental tissue that is not caused by bacteria[5], with global prevalence varying widely between 0 and 97%, even within a specific country[6]. In ETW, dental erosion is the main etiological factor[7], wherein the chemical influence is an extrinsic acid, such as that introduced via diet and medication, and/or intrinsic acid, such as that occurring due to gastroesophageal reflux and vomiting[8]. For an acid attack to have a clinically-significant effect, exposure must be frequent and/or prolonged[9]. Biological factors, such as saliva, acquired film, tooth structure, and the position of a tooth in relation to soft tissue and the tongue are associated with the pathogeny of ETW[5]. Moreover, behavioral factors, including eating, drinking, and oral hygiene habits, are predisposing factors for ETW[10].

Epidemiological studies conducted in Mexico have reported a prevalence of ETW of between 32 and 64% in adolescents[11,12], while the consumption of sweet carbonated drinks has been found to be associated with a higher prevalence of the condition[13–15].

Acidic drinks, such as sweet carbonated drinks, have been one of the most researched factors in the study of the condition subject to the present research. *In-vitro* studies have found that low pH beverages weaken the calcium and phosphate binding found in the mineral composition of enamel and dentin, leading to the release of these substances[16].

Adolescents consume high volumes of sweet carbonated drinks, corresponding to an average of almost one liter per day[13]. In Mexico, sweet carbonated drinks are consumed daily by 74% of the population, with an annual average 115 liters consumed per person[17]. It has been postulated that there may be common etiological factors between ETW and dental caries, such as the high or constant sweet carbonated drinks consumption, reduced salivary secretion, and unhealthy eating habits[18]. Few studies have reported on the relationship between the caries experience (CE) and ETW, indicating that adolescents with ETW present higher levels of caries[14,18]; however, other studies have not found such an association[19,20]. Considering the importance of the studies that report ETW in adolescents and their contradictory results, the objective proposed for this case-control study was to analyze the association between CE and ETW in a group of adolescents 13–14 years old from Mexico City.

MATERIALS AND METHOD

The present study was conducted on cases and controls identified from the findings of a previous cohort study[21]. The research protocol was submitted to the ethics committee of the Iztacala Faculty of Higher Studies of the National Autonomous University of Mexico (CE/FESI/032019/1287). The subjects' parents or guardians provided their signed informed consent, while consent to participate in the study was also requested from the subjects themselves. The present study was carried out in adherence to the guidelines of the Strengthening the Reporting of Observational Studies (STROBE) statement.

Participants

The cases subject to the present research were identified under the criteria that the subject presented at least two teeth affected by codes 2 or 3 of the basic erosive wear examination (BEWE)[22]. Ninety-seven subjects of the 424 considered were identified and accepted for participation as "cases with distinctive defect" and sex-matched with a group of controls and a group of "cases with initial surface texture loss". The group of cases with initial surface texture loss was selected under the criteria that the subject presented at least two teeth affected by BEWE Code 1 and no teeth affected by either codes 2 or 3. The controls were selected from those participants presenting a BEWE score equal to zero.

A total of 291 adolescents 13–14 years old participated in the study, corresponding to the cases presenting a distinctive defect (n = 97), those presenting initial surface texture loss (n = 97), and the control group (n = 97). The sample size per group ensured, with a 95% confidence interval, that the estimation of the odds ratio (OR) did not underestimate the true OR by more than 50% of its real value[23].

Data collection

For both the case and control groups, all the vestibular, palatal/lingual, and occlusal/incisal surfaces of the teeth selected were reexamined. The operational definition for the dependent variable (ETW) was based on the BEWE criteria, as follows: 0 = No erosive tooth wear; 1 = Initial loss of surface texture; 2 = Distinctive defect, corresponding to the loss of $<50\%$ of hard tissue from the surface; and 3 = Hard tissue loss corresponding to $\geq 50\%$ of the surface[22].

The main independent variable was CE, for which the World Health Organization criteria for Decayed (D), Missing (M), and Filled (F) teeth (known as the DMFT index) was applied on the permanent dentition of the groups studied[24]. The oral examination included the inspection and evaluation of debris and dental calculus, with all vestibular and palatal/lingual surfaces clinically classified using the Oral Hygiene Index (OHI) proposed by Green and Vermillion[25].

An examiner performed all oral examinations, for the purposes of which he participated in a pre-study calibration exercise (theoretical training) with the BEWE, DMFT, and OHI indices, which was then standardized by gold standard evaluators, obtaining scores, via Cohen's kappa coefficients for intra-rater reliability, of 0.93, 0.84 and 0.89 for BEWE, DMFT, and OHI, respectively. The oral examination was performed in a multipurpose classroom in each school, in which the adolescent was asked to sit in a school chair with their oral cavity illuminated with artificial light throughout the examination, which used a PCP11 probe (Hu-Friedy, Chicago, Ill., USA), a dental mirror (Arain, Sialkot, Punjab, Pakistan), and gauze.

The parameters of the stimulated saliva collected were the salivary flow rate, the pH, and the salivary buffer capacity. First, the saliva production was stimulated with an unflavored chewing gum for five minutes, while the rate per minute was obtained by weighing the saliva on a weighing scale (YS™ Series, Ohaus Corporation). Subsequently, a pH-measuring electrode (Starter ST2100™; Ohaus Corporation) was introduced to obtain the pH value of the stimulated saliva. Finally,

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a Saliva-Check Buffer™ kit (GC America Inc.) strip was used to obtain the buffer capacity. These measurements were taken in the morning, between 8:00 and 10:00 AM, with the participants directed to neither consume food nor brush their teeth an hour prior to that time.

A validated questionnaire, which included a section on the frequency of food and beverage consumption and which had been used in a previous study[12], was then applied. The following variables were recorded: age (in full years); sex (male/female); mother's level of educational attainment (years of completed study); visits to the dentist in the last 12 months (no/yes); weekly intake of sweet carbonated drink (portion of 500 mL); weekly intake of fruit juice (portion of 500 mL); weekly intake of milk (portion of 500 mL); weekly intake of citrus fruit (portion of 100 g); retain/rinse before swallowing (no/sometimes/yes); drink sweet carbonated drink or fruit juice before bed (no/sometimes/yes); suck lemons (no/sometimes/yes); consume chewable vitamin C (no/sometimes/yes); suffer from gastroesophageal reflux (no/yes); suffer from frequent vomiting (no/yes); and, tooth brushing frequency (times per day).

Data analysis

All the analysis was carried out using the statistical package Stata v. 14 (Stata Corp, College Station, TX, USA). The cases (with either initial surface texture loss or distinctive defect) and controls were compared according to their demographic and clinical characteristics: the risk indicators (weekly intake of sweet carbonated drink, fruit juice, milk, and citrus, retention or rinsing before swallowing, intake of sweet carbonated drink or fruit juice before bed, sucking of lemons, consumption of chewable vitamin C, gastroesophageal reflux, and frequent vomiting); dental hygiene variables (the presence of debris and dental calculus and tooth brushing frequency); salivary parameters (stimulated salivary flow rate, pH of stimulated saliva, and buffer capacity); and, the main variable (CE, according to the DMFT). For all comparisons between cases (with either initial surface texture loss or distinctive defect) and controls, the Chi-squared test was used for categorical variables and the Wilcoxon rank test for quantitative measurements, as all the quantitative variables did not present a normal distribution (Shapiro-Wilk test, $p < 0.001$). Multinomial logistic regression models were adjusted between the controls and the cases (with either initial surface texture loss or a distinctive defect), including all variables that resulted in a p value < 0.250 in the bivariate analysis, while p values < 0.05 were considered statistically significant.

RESULTS

Table 1 shows the comparison of the sociodemographic variables pertaining to the cases and controls, which revealed no significant differences among groups by age, sex, mother's educational attainment, and visits to the dentist in the last 12 months ($p > 0.05$). The mean BEWE score for the cases with distinctive defect was 4.77 $\pm$ 0.93 and 2.01 $\pm$ 0.54 for the cases with initial surface texture loss ($p < 0.001$).

Table 2 presents the comparison of the risk indicators, wherein the cases with distinctive defect presented a lower level of weekly milk consumption (500 mL) (4.08 $\pm$ 3.37) than the cases with initial surface texture loss (4.98 $\pm$ 3.40) and the controls (5.19 $\pm$ 3.42) ($p = 0.043$). The weekly intake of sweet carbonated drink (500 mL) was 3.22 $\pm$ 4.18 for the cases with distinctive defect, 2.90 $\pm$ 3.08 for the cases with initial loss and 1.98 $\pm$ 1.96 for the control group, ($p = 0.083$).

Table 3 presents the comparison of CE, dental hygiene, and salivary parameters. With regard to CE, the cases with distinctive defect (6.96 $\pm$ 4.61) and initial surface texture loss (6.36 $\pm$ 4.02) presented a higher DMFT index score than the controls (5.43 $\pm$ 4.14) ($p = 0.040$), while no significant differences were observed between groups for both dental hygiene and salivary parameters ($p > 0.05$).

The final multinomial logistic regression model (Table 4) showed that, for each tooth with CE, adolescents were 9% more likely to become a case with a distinctive defect than the controls (OR = 1.09 (95% CI: 1.01–1.17); $p = 0.020$). For each portion of intake of sweet carbonated drink, a 16% increase was observed (OR = 1.16 (95% CI: 1.03–1.31); p = 0.012). Finally, the adolescents who reported frequent vomiting were 3.19 times more likely to be a case with a distinctive defect (OR = 3.19 (95% CI: 1.02–10.01); $p = 0.047$).

DISCUSSION

The findings of the present study show an association between CE and the presence of ETW. The sweet carbonated drink consumption was shown to be associated, in general, with the presence of ETW, in terms of both initial surface texture loss and more severe loss, while frequent vomiting was shown to be associated with severe ETW in the study sample.

The present study is the first to be conducted on cases and controls for ETW in the Mexican population, in which the prevalence of caries is among the highest in the world for adolescents[26], the group which presents the highest levels of one of the most-frequently studied factors associated ETW, sweet carbonated drink consumption[17]. The cases were identified from a cohort study previously carried out on an open population (not volunteers from dental clinics or hospitals) and with controls selected from the same population, which helps with the comparability between groups[21]. A group of cases with initial wear was selected as a comparison group, in which advanced erosive wear (a distinctive defect) had not been detected at the time of the study.

Among the weaknesses of the study is the possible memory bias regarding beverage and citrus fruit consumption, while another is that the information on gastroesophageal reflux and frequent vomiting was obtained from a self-reported questionnaire, as it was not possible to include a specialist diagnosis.

Like other reports[14,18,27], the present study found that the presence of teeth with CE is associated with ETW. However, there are studies that have not found such an association[19,20]. Although dental caries and ETW share etiological factors[18], the differences among reports may be due to the different conditions in each country in terms of habits, education, and access to health services, among others.

On the other hand, the present study found an association between the sweet carbonated drink consumption and ETW, with the former reported as a factor associated with ETW in

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Table 1: Comparison of the sociodemographic variables and basic erosive wear examination (BEWE).

Variable	Cases with distinctive defect n = 97	Cases with initial surface texture loss n = 97	Controls n = 97	$p^{\dagger}$
Sex				
Male	45 (46.4%)	45 (46.4%)	45 (46.4%)	1.000
Female	52 (53.6%)	52 (53.6%)	52 (53.6%)	
Age				
mean s. d.	13.71 ± 0.59	13.74 ± 0.48	13.61 ± 0.53	0.182
(median)	(14)	(14)	(14)	
Mother's schooling				
Did not know‡	7 (7.2%)	7 (7.2%)	6 (6.2%)	0.997
>9 years of education	46 (47.4%)	45 (46.4%)	45 (46.4%)	
≤9 years of education	44 (45.4%)	45 (46.4%)	46 (47.4%)	
Visits to the dentist ≤12 months				
No	72 (74.2%)	72 (74.2%)	65 (67.0%)	0.435
Yes	25 (25.8%)	25 (25.8%)	32 (33.0%)	
BEWE score				
mean s. d.	4.77 ± 0.93	2.01 ± 0.54	0.0 ± 0.0	<0.001
(median)	(4)	(2)	(0)	

† *Wilcoxon rank test and Chi square were used to compare quantitative and categorical variables, respectively;* ‡ *They did not know her or did not live with her.*

Table 2: Comparison of the risk indicators for erosive tooth wear.

Variable	Cases with distinctive defect n = 97	Cases with initial surface texture loss n = 97	Controls n = 97	$p^{\dagger}$
Sweet carbonated drink (portion of 500 mL)				
mean s. d.	3.22 ± 4.18	2.90 ± 3.08	1.98 ± 1.96	0.083
(median)	(1.75)	(2.10)	(1.40)	
Fruit juice (portion of 500 mL)‡				
mean s. d.	2.06 ± 1.75	2.36 ± 2.58	1.98 ± 2.21	0.488
(median)	(1.75)	(1.40)	(1.40)	
Milk (portion of 500 mL)				
mean s. d.	4.08 ± 3.37	4.98 ± 3.40	5.19 ± 3.42	0.043
(median)	(3.50)	(4.55)	(4.90)	
Retain/rinse before swallowing				
No	62 (63.9%)	63 (64.9%)	67 (69.1%)	0.602
Sometimes	23 (23.7%)	19 (19.6%)	22 (22.7%)	
Yes	12 (12.4%)	15 (15.5%)	8 (8.25%)	
Sweet carbonated drink or fruit juice before bed				
No	37 (38.1%)	44 (45.4%)	36 (37.1%)	0.525
Sometimes	31 (32.0%)	33 (34.0%)	37 (38.1%)	
Yes	29 (29.9%)	20 (20.6%)	24 (24.7%)	
Citrus fruit (portion of 100 gr)				
mean s. d.	6.72 ± 6.53	7.54 ± 7.93	5.43 ± 5.66	0.260
(median)	(4.88)	(4.64)	(3.48)	
Suck lemons				
No	27 (27.8%)	20 (20.6%)	21 (21.6%)	0.783
Sometimes	31 (32.0%)	36 (37.1%)	35 (36.1%)	
Yes	39 (40.2%)	41 (42.3%)	41 (42.3%)	
Consume chewable vitamin C				
No	68 (70.1%)	65 (67.0%)	68 (70.1%)	0.827
Sometimes	20 (20.6%)	24 (24.7%)	20 (20.6%)	
Yes	9 (9.3%)	8 (8.3%)	9 (9.3%)	
Gastroesophageal reflux				
No	60 (61.9%)	68 (70.1%)	69 (71.1%)	0.318
Yes	37 (38.1%)	29 (29.9%)	28 (28.9%)	
Frequent vomiting				
No	85 (87.6%)	92 (94.8%)	92 (94.8%)	0.090
Yes	12 (12.4%)	5 (5.1%)	5 (5.1%)	

† *Wilcoxon rank test and Chi square were used to compare quantitative and categorical variables, respectively;* ‡ *It includes artificial and natural.*

Table 3: Comparison of caries experience, dental hygiene, and salivary parameters.

Variable	Cases with distinctive defect n=97	Cases with initial surface texture loss n=97	Controls n=97	$p^{\dagger}$
DMFT‡				
mean s. d.	6.96 ± 4.61	6.36 ± 4.02	5.43 ± 4.14	0.040
(median)	(6)	(6)	(5)	
Decayed				
mean s. d.	6.14 ± 4.47	5.46 ± 3.95	4.77 ± 3.72	0.116
(median)	(6)	(5)	(5)	
Filled				
No	70 (72.2%)	70 (72.2%)	75 (77.3%)	0.641
Yes	27 (27.8%)	27 (27.8%)	22 (22.7%)	
Missing				
No	95 (97.9%)	94 (96.9%)	94 (96.9%)	1.000
Yes	2 (2.1%)	3 (3.1%)	3 (3.1%)	
Debris (% of covered surfaces)				
mean s. d.	19.16 ± 12.81	20.04 ± 13.60	23.65 ± 17.45	0.336
(median)	(16.07)	(17.86)	(21.43)	
Dental calculus				
No	73 (75.3%)	67 (69.1%)	63 (64.9%)	0.290
Yes	24 (24.7%)	30 (30.9%)	34 (35.0%)	
Tooth brushing				
1 time	10 (10.3%)	10 (10.3%)	11 (11.3%)	0.483
2 times	84 (86.6%)	78 (80.4%)	78 (80.4%)	
3 times	3 (3.1%)	9 (9.3%)	8 (8.3%)	
Saliva flow rate (mL/min)				
mean s. d.	1.05 ± 0.59	1.13 ± 0.55	1.08 ± 0.50	0.569
(median)	(1.03)	(1.06)	(0.99)	
pH of saliva				
mean s. d.	7.25 ± 0.28	7.26 ± 0.28	7.31 ± 0.29	0.115
(median)	(7.25)	(7.29)	(7.33)	
Saliva buffer capacity				
High	7 (7.2%)	11 (11.3%)	12 (12.4%)	0.584
Medium	60 (61.9%)	62 (63.9%)	63 (64.9%)	
Low	30 (30.9%)	24 (24.7%)	22 (22.7%)	

† Wilcoxon rank test and Chi square (Fisher's test for missing teeth) were used to compare quantitative and categorical variables, respectively; ‡ Decayed, missing, and filled teeth index.

both the Mexican population and other parts of the world [11]. A recently published meta-analysis [28], conducted on 52 articles, found that a considerable variety of drinks, foods, and dietary habits were associated with the presence of ETW; however, carbonated drinks were the most consistent indicator of risk.

Finally, the present study found an association between frequent vomiting and ETW, which concurs with the results of a meta-analysis that showed that patients with eating disorders and self-induced vomiting have a high probability of presenting ETW [29]. The gastric juice that rises up via the esophagus and comes into contact with the structures of the oral cavity, including the teeth, can cause ETW, as the pH of the juice is even more acidic than that of drinks and foods with erosive potential [30]. Furthermore, it has been found that adolescents who present frequent vomiting also present a high consumption of acidic foods and drinks, such as carbonated drinks [31].

It has been shown that in adolescents, the teeth most affected by erosive wear are the lower first molars and upper anterior teeth [21]. ETW in lower molars are mainly located on the occlusal surface, while in upper anterior teeth these are situated on the palatal surface [32]. This could be because these permanent teeth erupt first and are therefore exposed to etiological factors for a longer time.

On the other hand, gastric juice that comes into contact with hard dental tissues from frequent vomiting or gastroesophageal disease can result in loss of enamel and dentin from the palatal surfaces of the upper incisors [30]. In the case of lower molars, the loss of tissue on their occlusal surface may be explained by the interaction of attrition and abrasive diets after acid challenges [4].

Preventive management of ETW should focus to reduce or stop the progression of the lesions. Information on clinical presentation and etiological factors should be analyzed carefully [33]. A record should be made of the foods and drinks that they habitually consume, including specific eating and drinking habits. The dentist may play an important role in detecting relevant disorders, such as frequent vomiting and gastroesophageal reflux [8]. Whenever possible, the clinical examination should be accompanied by measurement of the salivary flow rate [34].

When intrinsic acid sources are suspected to be the main causal factor, then referral to a specialist or a general practitioner is advised [33]. If the food diary suggests that extrinsic erosive sources are a significant causal factor, must recom-

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Table 4: Adjusted multinomial logistic regression models of cases with erosive tooth wear and their relationship with caries experience and risk indicators.

	Models adjusted for age and sex†						Complete model‡					
	Cases with initial surface texture loss			Cases with distinctive defect			Cases with initial surface texture loss			Cases with distinctive defect		
Variables	OR§	(95% CI)	p	OR§	(95% CI)	p	OR§	(95% CI)	p	OR§	(95% CI)	p
DMFT¶ Reference <1 tooth	1.05	(0.98–1.13)	0.151	1.10	(1.02–1.18)	0.009	1.05	(0.98–1.13)	0.188	1.09	(1.01–1.17)	0.020
Sweet carbonated drink Reference <500 mL	1.13	(1.01–1.26)	0.047	1.16	(1.03–1.30)	0.013	1.13	(1.01–1.27)	0.047	1.16	(1.03–1.31)	0.012
Milk Reference <500mL	0.98	(0.90–1.06)	0.601	0.90	(0.83–0.99)	0.024	0.99	(0.91–1.07)	0.738	0.92	(0.84–1.01)	0.069
Frequent vomiting Reference = No	0.91	(0.25–3.28)	0.887	2.73	(0.92–8.13)	0.071	1.02	(0.28–3.72)	0.980	3.19	(1.02–10.01)	0.047
pH of saliva Reference <7	0.67	(0.23–1.89)	0.444	0.51	(0.18–1.43)	0.199	-	-	-	-	-	-

† It includes each variable adjusted for age and sex; ‡ It includes all listed variables, age and sex; §Reference: controls; ¶Decayed, missing, and filled teeth index.

mend reducing the frequency of consumption of the identified erosive foods and beverages [34]. Products (*e.g.*, toothpastes or mouth rinses) containing stannous fluoride have the potential for slowing the progression of ETW [35].

Future studies on ETW and its relationship with intrinsic sources of acid should include a diagnosis made by a specialist and adhere to a longitudinal design that enables causality to be established.

CONCLUSIONS

The preventive management of both ETW and dental caries should aim to reduce exposure to foods and beverages with high acid and sugar content, such as sweet carbonated drinks. ETW can be an indicator of the presence of gastric acid, which, although it may be less common than extrinsic sources of acids (food, beverages, and medications), may suggest the need for a more in-depth study to determine the presence of a condition that may be exposing teeth to said acid.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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