RESEARCH PAPER

Dental Erosion and Oral Health Status Induced by Soft Drinks Among Children of Intermediate Schools in Duhok city /Kurdistan Region of Iraq

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Abstract
Background: Sugar-sweetened beverages have a major influence on oral and dental health by causing negative consequences.
Aim: To determine the dental erosion (DE) prevalence and its correlation with commonly taken beverages (sugar-sweetened and carbonated soft drinks) among 12-15 years-old intermediate school adolescents in the city of Duhok and the relation of parental education on adolescent dietary behaviour.
Material and method: A total of 480 students were randomly selected from 10 intermediate schools in socioeconomically diverse areas of Duhok. Dental erosion was assessed on the labial surfaces of all teeth using the Basic Erosive Wear Examination (BEWE) scoring system. Data on beverage consumption were collected through questionnaires. Oral health status was evaluated using the WHO criteria for Decayed, Missing, and Filled Teeth (DMFT), Plaque Index (PI), and Gingival Index (GI). Data were analyzed using SPSS software.
Results: High consumption of juices (92.9%), soft drinks (88.8%), and energy drinks (56%) were reported, mainly between meals. Mean DMFT was 3.51, indicating moderate decay. Plaque and gingival indices showed moderate plaque and mild-to-moderate inflammation. Dental erosion occurred in about two-thirds of students (median BEWE of 5.0). Lower parental education and energy drink intake were associated with poorer oral health outcomes. In negative binomial regression, the BEWE score was independently associated with energy drink consumption and age in intermediary children in this study.
Conclusions: Poor oral hygiene, high sugary drink consumption, and low parental education contribute to increased dental caries, periodontal disease, and erosion among Duhok adolescents.
Keywords: Dental erosion, sugar-sweetened beverage, Energy drinks, Parental education, Oral health
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INTRODUCTION

Dental erosion (DE) is defined as non-carious chemical loss of dental tissues in the bacterial absence. Based on the etiological acids origin, tooth erosion classified into extrinsic or intrinsic factors as extrinsic include a dietary acids combination exist in beverages, specific medications, occupational or environmental and lifestyle factors producing batteries as electrolytic/galvanic, wine tasters, etc. The extrinsic factors in childhood for DE are related to dietary acids or the origins of medicine and also to behavioral factors.[1]

The soft drinks consumption i.e., juices of acidic fruits, artificially and beverages as carbonated is the significantly risk element mostly associated with the dental defect of hard tissue.[2] Behavior and lifestyle differences should consider also as important in the DE etiology.[3] Hardness loss as the start of the surface softening is noticed in enamel erosion, following permanent tooth volume loss due to the enamel crystals dissolution. After the attack of initial acid, the remaining enamel surface layer remarkably becomes softer.[4]

It is assumed theoretically that re-mineralization and repairing are possible still at the early process of enamel erosion stage due to the residual enamel might behave as a scaffold and as supportive for the damaged tissues repair. Nevertheless, the enamel tissue repair is not possible as the outer enamel layer is devoid totally of minerals in the advanced erosion process stage. Possible DE effects include dentine hyper-sensitivity, pain, compromised esthetics, temporomandibular dysfunctions, pulp exposure, and oral functions reduction.[5]

In dental erosive wear development, interactions are needed that include factors such as biological, chemical, diet, behavioral, socioeconomic, time, education, knowledge, and general health.[6] In association with periodontal disease and dental caries, DE is considered now a worldwide common oral health issue.[7]

This study investigated the prevalence of dental erosion among adolescents in Duhok, Iraqi Kurdistan, and examines its association with beverage consumption and oral health status. Oral health was assessed using DMFT, plaque, and gingival indices. The study fills the regional knowledge gap by assessing the contribution of the frequent intake of juices and carbonated soft drinks to dental erosion, which is useful in the prevention and management of the condition in pediatric dentistry.

MATERIALS AND METHODS

Study design and sampling

A cross-sectional study was performed from 10 randomly chosen intermediate schools across different geographic zones of Duhok to examine the DE prevalence induced by soft drinks and evaluate its link with the status of oral health in teenagers aged 12 to 15 years. Students with equal representation from the western and eastern sectors of Duhok were included in this study. A cross-sectional

study was carried out among adolescents within the age range of 12–15 years enrolled in 10 intermediate schools located in Duhok City. We selected 10 intermediate schools of the available 121 schools through simple random sampling. We checked the names of the schools to be sure that the schools have been selected from both eastern and western areas of the city. We determined the sample size using the Cochrane Formula, considering the population of 29,577 intermediate school students, a 95% confidence level, a 5% margin of error, and a prevalence rate of 50%. The determined sample using this procedure was 380 people. Of the 10 selected schools, we selected the number of students from each school based on the proportion. In this regard, we tried to include 38 students in each school. Furthermore, we divided these students by the number of classes within each school. In this regard, the students were selected randomly from the predetermined random digit numbers using systematic random sampling. The lists of the students had the pre-determined numbers; therefore, we included the students based on these numbers. However, we increased our sample size to compensate for any missing information and rejection , so we take 480 student for this study , 48 participant from each school.

Data collection

Informed consent was obtained from the administration of the schools. In addition, the students were informed on the objectives of the study. All participants' confidentiality and privacy were maintained strictly. KoboToolbox was used as the data collection tool to facilitate secure and efficient mobile-based data entry. Each student completed a structured questionnaire that collected general information, including age, gender, dietary habits, and the consumption of beverages such as juices, carbonated soft drinks, and energy drinks. Clinical examinations were conducted at the participants' schools using disposable mouth mirrors, explorers, gauze, tweezers, gloves, masks, protective eyewear, gowns, and headlights for illumination. The study was carried out in Duhok from December 2024 to March 2025.

Measurements

Dental erosive wear was assessed using the BEWE index according to the standardized criteria for identifying erosive lesions and distinguishing them from abrasion and attrition. The BEWE system serves as a basic dental tool which dentists use to measure acid-based tooth erosion. The system enables dentists to conduct patient assessments while tracking disease development and determining treatment approaches. The mouth is divided into six sextants; Upper right posterior, Upper anterior, Upper left posterior, Lower left posterior, Lower anterior, and Lower right posterior. The sextant assessment process requires assessment of the most damaged tooth surface within each individual sextant. The examiner uses a dental mirror and proper lighting to conduct a visual assessment after drying the teeth. The scoring system ranges from 0 to 3; Score 0: No erosive tooth wear, Score 1: Initial loss of surface texture, Score 2: Distinct defect with hard tissue loss involving less than 50% of the surface area, and Score 3: Hard tissue loss involving 50% or more of the surface area. The total BEWE score results from adding the highest score obtained from each sextant. Therefore, the total score ranges from 0 to 18. The interpretation is generally as follows: 0-2 (No risk) requires routine maintenance and observation, while 3-8 (low risk) needs preventive advice and periodic review and 9-13 (medium risk) requires more detailed preventive measures and monitoring, whereas 14 or higher (high risk) needs intensive management and possible restorative treatment. [8]Buccal/labial tooth surfaces were examined for enamel loss and dentin. Mesial and distal surfaces were excluded due to contact areas between teeth.[9]

Dental caries was evaluated clinically using the DMFT index following the guidelines of the World Health Organization,[10]. The index recorded decayed (D), missing (M), and filled (F) permanent teeth, while dmft for primary teeth was excluded. Teeth missing for reasons other than caries were also excluded. The permanent teeth were identified using the Palmer notation system, excluding third molars and supernumerary teeth.[11] . The clinical examination was conducted in a systematic manner from the upper right first molar to the lower left first molar, and the findings were recorded using the WHO numerical coding system.

The level of dental plaque was determined using the Plaque Index (PI), which was developed by Silness & Löe . Dental plaque was recorded on six index teeth, 16, 12, 24, 36, 32, and 44. Gingival health was determined using the Gingival Index (GI), which is a measure of marginal and interdental gingival inflammation, scored on a scale of 0 to 3.[12 & 23]

The general and medical characteristics of intermediate schools were presented in descriptive statistics. Practices of soft drink consumption in intermediate schools were determined in number and percentage. The normality of the DMFT, GI, and PI was confirmed using a Q-Q norm. Therefore, the assessment of oral health status using DMFT (Decayed, Missing, and Filled Teeth) index, plaque index, and gingival index were determined in mean (SD). The Q-Q norm did not confirm the normality of the BEWE, therefore, we used the Median (Med) and IQR (Interquartile range). Explore the influence of beverages oral health status was examined in an independent t-test or one-way ANOVA. The difference of dental erosion among children characteristics was examined in Mann-Whiteny U-test (for variables with two choices) and Kruskal Wallis test (for variables with more than two choices) tests. The relationship between BEWE and the Plaque Index (PI), Gingival Index (GI), and Decayed, Missing, and Filled Teeth (DMFT) index was examined using Pearson's correlation coefficient. The predicting factors of the dental erosion in intermediate school students were examined in generalized regression (quantile regression). Predictors of dental erosion in intermediate schools were examined in linear regression. The statistical calculations were performed using JMP®, Version 18.0. SAS Institute Inc., Cary, NC, 1989–2023. The Kappa score of the reliability was 0.89 in this study.

RESULTS

Soft drink consumption patterns are depicted in Table (1). A significant number of children were found to consume juices (92.9%), carbonated drinks (88.8%) and more than half (56%) energy drinks. Juices and carbonated drinks were mostly taken once daily, and the proportions for the two were 55.2% and 48.8%, respectively, while 43.8% never had energy drinks. During the day, 69.4% of the total drinkers had their beverages between meals and 90.8% at school. In addition to that, smoking habits were quite evident, as 39.4% confessed to being smokers in some way—hookah (19.4%), cigarettes (15.2%), or vaping (23.8%).

Table(1): *Practices of soft drink consumption in intermediate schools in Duhok city*

Soft drink consumption (n=480)	**Statistics**	
	Number	**Percent**
Consuming Beverages		
Juices	446	92.92
Carbonated soft drinks	426	88.75
Energy drinks	269	56.04
Frequency of Consuming Beverages		
Juices		
Never	1	0.21
Not often	188	39.17
One a day	265	55.21
Twice a day	15	3.13
More	11	2.29
Carbonated soft drinks		
Never	2	0.42
Not often	198	41.25
One a day	234	48.75
Twice a day	25	5.21
More	21	4.38
Energy drinks		
Never	210	43.75
Not often	140	29.17
One a day	92	19.17
Twice a day	22	4.58
More	16	3.33
Time of Consuming Beverages		
At meal	158	32.92
Between meals	333	69.38
at school	436	90.83
Smoking status		
Smoking	189	39.38
Hookah	93	19.38
Cigarette	73	15.21
Vape	114	23.75

The oral health assessment is summarized in Table (2) The mean DMFT score was 3.51 (±2.50), which points to a moderate dental decay experience. The mean PI was 0.85 (±0.22), indicating the presence of moderate plaque, while the mean GI was 0.78 (±0.25), implying mild to moderate gingival inflammation. The average BEWE score was 0.68 (±0.51), and two-thirds of the students (66.3%) experienced dental erosion, thus reinforcing the fact that this is a significant problem in this population.

Table(2) : *Assessment of oral health status using DMFT (Decayed, Missing, and Filled Teeth) index, plaque index, and gingival index and dental erosion*

Oral health status (n=480)	**Min-Max**	**Mean**	**Standard deviation**
DMFT	0-14	3.51	2.50
PI	0.13-1.71	0.85	0.22
GI	0.08-1.58	0.78	0.25
BEWE	0-3	0.68	0.51
		No.	**%**
Dental erosion			
No dental erosion		162	33.75
Dental erosion		318	66.25

In Table (3) for the DMFT indicator, the mean numbers for both non-consumers (3.35 ± 2.40) and consumers (3.52 ± 2.51) were found to be similar in juice consumption, and there was no significant difference (p = 0.704) between them. Other soft-drink consumption was also not significant, with non-consumers averaging 3.74 ± 2.99 and consumers 3.48 ± 2.43 (p = 0.473). On the contrary, energy-drink consumption was significantly associated with DMFT, where the average DMFT for consumers was 3.72 ± 2.51 while non-consumers had a lower mean of 3.24 ± 2.47 (p = 0.037). The frequency of juice (p = 0.928), carbonated soft drink (p = 0.182), and energy drink (p = 0.102) did not indicate statistically significant differences in DMFT, however, the most frequent consumers had the highest average, particularly for carbonated soft drinks (4.62 ± 3.34 in the "more" category).

According to the Gingival Index (GI) in Table (3) , the consumption of juice was not significant, with non-consumers having an average of 0.82 ± 0.29 and consumers having an average of 0.77 ± 0.25 (p = 0.265). Similarly, the consumption of carbonated soft drinks did not show a significant difference (0.77 ± 0.27 vs. 0.78 ± 0.25, p = 0.716), as well as the consumption of energy drinks (0.77 ± 0.27 vs. 0.79 ± 0.24, p = 0.330). On the other hand, the frequency of carbonated soft drink consumption was a significant factor related to GI (p = 0.008), which was increased from 0.75 ± 0.26 in those who consumed infrequently to 0.84 ± 0.24 in those who consumed more frequently. Other variables related to frequency, as well as drinking at meals, between meals, or at school, did not reach statistical significance. Smoking was found to have a borderline association with GI, with non-smokers and smokers having means of 0.76 ± 0.25 and 0.81 ± 0.25, respectively (p = 0.052).

According to the Plaque Index (PI) data in Table (3), juice intake had no significant effect (0.91 ± 0.24 vs 0.84 ± 0.21, p = 0.099), nor did consumption of carbonated soft drinks (0.88 ± 0.26 vs 0.85 ± 0.21, p = 0.321) or energy drinks (both at approximately 0.85, p = 0.981). The frequency of carbonated soft drink intake was significantly associated with PI: p = 0.017, with PI values increasing from 0.83 ± 0.23 in infrequent consumers to the highest-frequency group at 0.87 ± 0.18. Other frequency measures and drinking behaviors were not significant. Smoking was associated with a PI increase close to being significant: 0.84 ± 0.21 in non-smokers vs 0.87 ± 0.22 in smokers (p = 0.094).

Table (3): *Explore the influence of beverages oral health status*

Characteristics (n=480)	DMFT Mean (SD)	p.value	PI Mean (SD)	p.value	GI Mean (SD)	p.value
Juices						
No	3.35 (2.40)	0.704	0.91 (0.24)	0.099	0.82 (0.29)	0.265
Yes	3.52 (2.51)		0.84 (0.21)		0.77 (0.25)	
Carbonated soft drinks						
No	3.74 (2.99)	0.473	0.88 (0.26)	0.321	0.77 (0.27)	0.716
Yes	3.48 (2.43)		0.85 (0.21)		0.78 (0.25)	
Energy drinks						
No	3.24 (2.47)	0.037	0.85 (0.23)	0.981	0.77 (0.27)	0.330
Yes	3.72 (2.51)		0.85 (0.20)		0.79 (0.24)	
Juices frequency						
Never	3.00 (.)	0.928	1.17 (.)	0.685	1.25 (.)	0.372

Not often One a day Twice a day More	3.47 (2.42) 3.50 (2.58) 3.80 (2.81) 4.09 (1.45)		0.85 (0.21) 0.85 (0.22) 0.84 (0.17) 0.85 (0.24)		0.79 (0.26) 0.77 (0.25) 0.75 (0.16) 0.81 (0.29)	
Carbonated soft drinks frequency Never Not often One a day Twice a day More	 3.00 (0.00) 3.49 (2.46) 3.50 (2.45) 2.80 (2.43) 4.62 (3.34)	0.182	 1.32 (0.21) 0.83 (0.23) 0.86 (0.19) 0.86 (0.34) 0.87 (0.18)	0.017	 1.32 (0.09) 0.75 (0.26) 0.79 (0.23) 0.81 (0.32) 0.84 (0.24)	0.008
Energy drinks frequency Never Not often One a day Twice a day More	 3.24 (2.47) 3.64 (2.34) 3.92 (2.54) 3.00 (2.35) 4.25 (3.68)	0.102	 0.85 (0.24) 0.83 (0.19) 0.87 (0.22) 0.92 (0.24) 0.85 (0.15)	0.389	 0.76 (0.27) 0.77 (0.24) 0.81 (0.23) 0.84 (0.22) 0.82 (0.22)	0.384
At meal No Yes	 3.42 (2.42) 3.70 (2.66)	0.239	 0.86 (0.22) 0.83 (0.21)	0.122	 0.79 (0.26) 0.75 (0.23)	0.143
Between meals No Yes	 3.22 (2.41) 3.64 (2.53)	0.088	 0.83 (0.23) 0.86 (0.21)	0.287	 0.76 (0.27) 0.78 (0.24)	0.447
at school No Yes	 3.68 (2.57) 3.49 (2.49)	0.634	 0.86 (0.23) 0.85 (0.22)	0.820	 0.78 (0.22) 0.78 (0.25)	0.978
smoking No Yes	 3.48 (2.48) 3.55 (2.53)	0.779	 0.84 (0.21) 0.87 (0.22)	0.094	 0.76 (0.25) 0.81 (0.25)	0.052
The independent t-test/one-way ANOVA was performed for statistical analyses. DMFT: Decayed, Missing, and Filled Teeth PI: Plaque Index GI: Gingival Index						

The unadjusted analysis showed that the distribution of BEWE scores was significantly associated with father's educational level and energy-drink consumption. In overall analysis, the association with father's education was statistically significant (p=0.031), but none of the pairwise comparisons were significant after adjustment for multiple testing. The median BEWE score was 1 in both energy-drink consumers and non-consumers, interquartile ranges were 2, but the distribution of BEWE scores was significantly different between the two groups (p=0.008). There were no statistically significant differences in BEWE by gender, city zone, mother's education, medical history, drug use, dental history, brushing frequency, juice consumption, carbonated soft-drink consumption, and beverage-consumption frequency (Table 4).

Table(4). *Characteristics associated with the recalculated BEWE score (n=480)*

Characteristics (n=480)	**Category**	**Outcome:** BEWE **BEWE median (IQR)**	**P**	**Test**
Gender	Male Female	1 (2) 1 (2)	0.358	Mann–Whitney U
City zone	East part West part	1 (2) 1 (2)	0.689	Mann–Whitney U
Mother education	Illiterate Read & write Primary Intermediate Secondary University	1 (1.75) 1 (2) 1 (2) 1 (1.75) 1 (2) 1 (2)	0.472	Kruskal–Wallis

Father education	Illiterate Read & write Primary Intermediate Secondary University	1 (2) 1 (2) 1 (1) 1 (2) 1 (1) 1 (2)	**0.031**	Kruskal–Wallis
Medical history	None Yes	1 (2) 1 (2)	0.732	Mann–Whitney U
Drugs used	No Yes	1 (2) 1 (2)	0.760	Mann–Whitney U
Dental history	None Yes	1 (2) 1 (2)	0.317	Mann–Whitney U
Brushing frequency	Not often Once daily Twice daily	1 (2) 1 (2) 1 (2)	0.270	Kruskal–Wallis
Juices	No Yes	1 (2) 1 (2)	0.623	Mann–Whitney U
Carbonated soft drinks	No Yes	1 (2) 1 (2)	0.340	Mann–Whitney U
Energy drinks	No Yes	1 (2) 1 (2)	**0.008**	Mann–Whitney U
Juices frequency	Never Not often One a day Twice a day More	2 (0) 1 (2) 1 (2) 1 (1) 2 (2.5)	0.468	Kruskal–Wallis
Carbonated soft drinks frequency	Never Not often One a day Twice a day More	2 (0) 1 (2) 1 (2) 1 (2) 1 (1)	0.830	Kruskal–Wallis
Energy drinks frequency	Never Not often One a day Twice a day More	1 (2) 1 (2) 1 (2) 1 (1) 1.5 (1)	0.094	Kruskal–Wallis
Two-category variables were analysed using the Mann–Whitney U test; variables with three or more categories were analysed using the Kruskal–Wallis test.				

Table 5 displays the correlations between BEWE and other oral indices. A positive correlation of BEWE with DMFT (r = 0.1753, p = 0.0001) was found, which means that the children having more decayed or filled teeth also exhibited more erosive wear to a certain degree. On the other hand, BEWE was not significantly related to either PI or GI, which means that erosion is not directly connected with plaque formation or gingival inflammation.

Table (5): *Relation of BEWE with PI, GI, and DMFT in intermediate schools in Duhok City*

Factors (n=480)	**Outcome: BEWE**	
	r	**p**
DMFT	0.1753	0.001
PI	0.0340	0.458
GI	0.0222	0.627
Pearson correlation was performed for statistical analyses.		

In negative binomial regression, the BEWE score was independently associated with energy-drink consumption and age. After adjustment for the other variables, energy-drink consumers had a 25.7% higher expected BEWE score than non-consumers (adjusted mean ratio=1.257, 95% CI: 1.039–1.521, p=0.019). The expected BEWE score increased by 11.9% with each additional year of age (adjusted mean ratio=1.119, 95% CI: 1.026–1.220, p=0.011). Brushing once daily was associated with a higher expected BEWE score than twice daily brushing, but the result was not statistically significant (adjusted mean ratio = 1.275, 95% CI: 0.978–1.661, p=0.072). There were no statistically significant independent associations with gender or juice consumption, smoking,

infrequent brushing, drug use, medical history, dental history or carbonated soft drink consumption.

Table(6). *Factors associated with the recalculated BEWE score: negative binomial regression*

	Outcome: BEWE score					
Factor	**β estimate**	**Robust SE**	**Adjusted mean ratio**	**Lower 95%**	**Upper 95%**	**P**
Intercept	-1.784	0.629	0.168	0.049	0.576	**0.005**
Energy drinks: Yes vs No	0.229	0.097	1.257	1.039	1.521	**0.019**
Smoking: Yes vs No	-0.162	0.102	0.851	0.697	1.039	0.112
Age: per one-year increase	0.112	0.044	1.119	1.026	1.220	**0.011**
Brushing: Not often vs Twice daily	0.118	0.128	1.126	0.876	1.446	0.354
Brushing: Once daily vs Twice daily	0.243	0.135	1.275	0.978	1.661	0.072
Drugs used: Yes vs No	-0.166	0.336	0.847	0.439	1.637	0.622
Medical history: Yes vs None	0.019	0.346	1.019	0.517	2.009	0.957
Dental history: Yes vs None	0.186	0.176	1.205	0.853	1.701	0.290
Carbonated soft drinks: Yes vs No	0.098	0.146	1.102	0.828	1.467	0.503
Gender: Female vs Male	0.113	0.095	1.120	0.929	1.350	0.235
Juices: Yes vs No	0.020	0.176	1.020	0.723	1.439	0.910
Dispersion parameter (alpha)	0.132	0.063				**0.036**

Model: negative binomial regression with log link and HC0 robust standard errors. Adjusted mean ratio = exp(β). Reference groups: no energy drinks, no smoking, brushing twice daily, no drug use, no medical history, no dental history, no carbonated soft drinks, male gender and no juice consumption. The dispersion parameter was 0.132 (p=0.036).

DISCUSSION

This cross-sectional study investigated the relationship between soft drink consumption and oral health status among 480 adolescents aged 12–15 years in Duhok City using the DMFT index, Plaque Index (PI), Gingival Index (GI), and Basic Erosive Wear Examination (BEWE). The findings demonstrated a high burden of oral diseases, with 88.3% of participants affected by dental caries, 53.9% presenting with periodontal disease, and 66.3% exhibiting dental erosion. These findings indicate that oral diseases remain a major public health concern among adolescents in this region and emphasize the need for preventive strategies targeting modifiable behavioral risk factors .[13&21]

The present study showed very high consumption of sugary and acidic beverages. More than 90% of participants consumed fruit juices, 88.8% consumed carbonated soft drinks, and over half reported consuming energy drinks. Most beverages were consumed between meals and at school, increasing the duration of acid exposure to the teeth and reducing the protective buffering effect of saliva. Similar findings have been reported in previous studies demonstrating that frequent exposure to acidic beverages contributes to enamel demineralization and increases the risk of dental erosion.[13,14,15 &16]

The oral health assessment revealed a mean DMFT score of 3.51, indicating a moderate caries experience, together with moderate plaque accumulation and mild-to-moderate gingival inflammation. In addition, approximately two-thirds of the participants had dental erosion. These findings agree with previous reports showing that adolescents with frequent exposure to sugary and acidic beverages commonly experience multiple oral health problems, including dental caries, gingivitis, and erosive tooth wear .[14,13&17]

A notable finding of this study was that energy drink consumption was significantly associated with higher DMFT scores. Adolescents who consumed energy drinks had significantly greater caries experience than non-consumers. This finding is biologically plausible because energy drinks usually contain high concentrations of fermentable sugars and organic acids, both of which contribute to enamel demineralization and promote cariogenic bacterial activity.[15&16]

In contrast, neither juice consumption nor carbonated soft drink consumption showed a statistically significant association with DMFT. Likewise, beverage consumption alone was not significantly associated with plaque or gingival index values. However, increasing frequency of carbonated soft drink consumption was associated with significantly higher plaque and gingival index scores. This suggests that the frequency of exposure may be more important than simple consumption status. Individuals who frequently consume soft drinks may also be more likely to have poor dietary

habits and inadequate oral hygiene, resulting in greater plaque accumulation and gingival inflammation .[10&16]

Regarding dental erosion, adolescents who consumed energy drinks demonstrated significantly higher BEWE scores than non-consumers in the univariate analysis, and increasing consumption frequency was also associated with greater erosive wear. Furthermore, energy drink consumption remained the only independent predictor of dental erosion in the multivariable regression model. This finding supports previous laboratory and epidemiological studies demonstrating the high erosive potential of energy drinks because of their low pH and high titratable acidity.[13,15&16]

The study also demonstrated that beverage consumption between meals was significantly associated with higher BEWE scores. Acidic drinks consumed between meals expose teeth to repeated acid attacks without the buffering effect that accompanies food intake, thereby increasing susceptibility to erosive tooth wear. This observation agrees with previous studies reporting that prolonged and repeated acid exposure is one of the principal determinants of dental erosion.[22&15]

Parental education also influenced oral health outcomes. Lower paternal educational level was significantly associated with greater dental erosion, suggesting that socioeconomic factors and parental health literacy influence adolescents' dietary behaviors and oral health practices. Parents with higher educational attainment may encourage healthier beverage choices, better oral hygiene practices, and greater utilization of preventive dental care, findings consistent with previous reports.[18&10]

A weak but significant positive correlation was observed between BEWE and DMFT, indicating that adolescents with greater erosive tooth wear also tended to have higher caries experience. Although dental caries and erosion have different pathological mechanisms, they share several common behavioral risk factors, particularly frequent consumption of sugary and acidic beverages. In contrast, BEWE was not significantly correlated with plaque or gingival indices, supporting the concept that dental erosion is primarily a chemically mediated process rather than a plaque-dependent disease.[22&20]

Overall, the findings suggest that dietary behaviors, particularly energy drink consumption, play a more important role in dental erosion than demographic characteristics or routine oral hygiene practices alone.School-based preventive programs should therefore emphasize reducing energy drink consumption, promoting healthier beverage choices, improving oral hygiene practices, and increasing parental awareness.

LIMITATIONS OF THE STUDY

This study was limited to adolescents from a single geographic area, which may restrict the generalizability of the findings. The observed inconsistencies in the associations between beverage consumption and dental erosion may reflect differences in population characteristics, fluoride exposure, oral hygiene practices, and other unmeasured confounding factors, highlighting the multifactorial nature of dental erosion. Although energy drink consumption was identified as an independent predictor of dental erosion in this cross-sectional study however this design is limited the assessment of causal relationships; future multicenter studies using more appropriate analytical designs, such as case-control or longitudinal studies, are recommended to validate these findings.

CLINICAL/PUBLIC-HEALTH IMPLICATION

The clinical and public health implications to this study can be implementing the school-based screening, nutritional counseling, and fluoride varnish/CPP-ACP for erosion-prone adolescents

CONCLUSIONS

Adolescents in Duhok exhibited a high prevalence of dental caries, periodontal disease, and dental erosion. Energy drink consumption was associated with higher caries experience and was independently associated with dental erosion and identified as a significant independent predictor in the multivariable regression model. Frequent carbonated soft drink intake was associated with poorer periodontal health, while lower paternal educational level was linked to greater dental erosion. These findings support the need for school-based oral health promotion programs focusing on reducing acidic beverage consumption, improving oral hygiene practices, and increasing parental awareness. Further longitudinal studies are recommended to confirm the causal relationship between beverage consumption and dental erosion.

ETHICAL APPROVAL

Ethical approval was obtained from the Research Ethics Committee and the General Health Directorate (Reference No.27112024-10-6 dated 27 November 2024), and access to the school was approved by the Duhok General Education Directorate (Order No. 16529, 6 November 2024). Parental consent was obtained.

CONFLICT OF INTEREST

The authors report no conflicts of interest.

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