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Original article

Oral Health Implications of Electronic Cigarette Use Among Libyan Young Adults: A Cross-Sectional Study

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ABSTRACT

Electronic cigarette (e-cigarette) consumption has escalated substantially among young adult populations globally; however, empirical evidence regarding its oral health consequences remains sparse, particularly within North African contexts. This investigation sought to examine the association between e-cigarette utilization patterns and dental caries prevalence among Libyan young adults. A descriptive cross-sectional investigation was conducted in Tripoli, Libya, enrolling 86 male participants aged 18–35 years who were current or former e-cigarette users. Data acquisition employed structured questionnaires to capture demographic characteristics and vaping behaviors (duration, frequency, device type, nicotine concentration, flavor preference, and pre-bedtime use), complemented by clinical oral examinations utilizing the Decayed, Missing, Filled Teeth (DMFT) index. Analytical approaches comprised descriptive statistics, independent t-tests, one-way ANOVA with post-hoc comparisons, and multiple linear regression modeling. The mean DMFT score was 5.9 (SD 4.2), with 32.6% of participants demonstrating high caries burden (DMFT ≥8). Significant associations emerged between elevated DMFT scores and prolonged usage duration ($p<0.001$), constant daily consumption ($p=0.002$), nicotine concentrations ≥30% ($p=0.038$), and vaping within one-hour preceding bedtime ($p=0.018$). Multivariate regression identified duration of use as the predominant independent predictor ($\beta=0.48$, $p<0.001$), with each additional year associated with a 0.89 increment in DMFT score. The model accounted for 48% of the variance in DMFT scores ($R^2=0.48$, $p<0.001$). Among Libyan male e-cigarette users, extended duration, frequent utilization, elevated nicotine strength, and bedtime vaping demonstrated independent associations with heightened caries severity. These findings underscore the imperative for dental clinicians to routinely assess e-cigarette use and implement targeted preventive interventions.

Introduction

Oral diseases afflict approximately 3.5 billion individuals globally, with dental caries in permanent dentition persisting as the most prevalent condition worldwide (1,2). Over the preceding decade, nicotine consumption patterns have undergone transformative changes attributable to the widespread adoption of electronic cigarettes (ECs), particularly among adolescent and young adult populations (3,4). Initially introduced circa 2006–2007 and promoted as harm reduction instruments, ECs have experienced exponential proliferation, engendering a novel cohort of nicotine users (5,6).

Electronic cigarettes constitute battery-powered devices that thermally degrade a liquid solution comprising nicotine, propylene glycol, vegetable glycerin, and flavoring agents to generate an inhalable aerosol (7). Upon heating, the e-liquid undergoes thermal degradation, yielding carbonyl compounds including formaldehyde, acetaldehyde, acrolein, and glyoxal (8,9). The oral cavity serves as the primary portal of entry, with dental structures, gingival tissues, oral mucosa, and salivary constituents subjected to exposure during each puff (10).

Several biologically plausible mechanisms establish connections between vaping and augmented caries risk. Salivary dysfunction and xerostomia, arising from the hygroscopic properties of propylene glycol and vegetable glycerin, compromise the mouth's intrinsic protective mechanisms (11,12). Direct chemical challenges from acidic e-liquids (pH 3–6) and fermentable sweeteners provide substrates for cariogenic bacteria such as *Streptococcus mutans* (13–15). Furthermore, modulation of the oral microbiome through increased abundance of acidogenic species and diminished commensal organisms creates a dysbiotic environment conducive to caries development (16,17).

Despite biological plausibility, epidemiological evidence remains constrained and geographically circumscribed (18,19). In Libya, where dental caries prevalence is elevated among young adults (20,21), no published investigations have systematically examined EC utilization or its oral health implications. This study aimed to investigate the association between electronic cigarette use and dental caries prevalence among Libyan young adults aged 18–35 years in Tripoli, and to characterize patterns of e-cigarette consumption among participants.

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Materials and methods

Study Design and Setting

This descriptive cross-sectional investigation was conducted in Tripoli, Libya, recruiting participants from dental clinics and university settings between 2023 and 2024. Ethical approval was obtained from the institutional research ethics committee, and all participants provided written informed consent prior to enrollment.

Study Population, Sample Size, and Sampling

The study population comprised young adults aged 18 to 35 years residing in Tripoli, Libya, who were current or former electronic cigarette users. Inclusion criteria required participants to be within the specified age range, resident in Tripoli, willing to provide informed consent, and either currently using or having previously used electronic cigarettes. Exclusion criteria encompassed current conventional cigarette smoking exclusively (without concurrent e-cigarette use), systemic diseases affecting salivary flow, or inability to complete the clinical examination. A total of 86 male participants meeting inclusion criteria were enrolled using convenience sampling methodology, with sample size determined by recruitment feasibility within the study period and availability of eligible participants attending the selected dental clinics and university settings.

Data Collection

Data were collected through two complementary approaches:

- **Questionnaire:** A self-structured questionnaire captured demographic characteristics (age, medical history), e-cigarette utilization patterns (duration, frequency, device type, nicotine concentration, flavor preference, pre-bedtime vaping), oral hygiene practices, and dietary habits.
- **Clinical Examination:** Clinical oral examinations assessed dental caries using the DMFT index (Decayed, Missing, Filled Teeth), salivary status, plaque index, and gingival condition.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics encompassed means, standard deviations, and percentages. Between-group comparisons employed independent t-tests and one-way ANOVA with Tukey HSD post-hoc tests for multiple comparisons. Multiple linear regression identified independent predictors of DMFT scores, with variables selected based on clinical relevance and bivariate associations ($p<0.20$). Statistical significance was established at $p<0.05$.

Results

Participant Demographics and Characteristics

A total of 86 male participants meeting inclusion criteria were enrolled. All participants were residents of Tripoli, Libya, and were either current or former electronic cigarette users. The majority were aged 18–24 years (55.8%, n=48), followed by those aged 25–30 years (37.2%, n=32), and 31–35 years (7.0%, n=6). The mean age was 24.8 years (SD 3.9), indicating a relatively young cohort with moderate age variability. Regarding medical history, the vast majority (90.7%, n=78) reported no significant medical conditions; a small proportion reported allergies (4.7%, n=4), asthma (2.3%, n=2), cardiac conditions (1.2%, n=1), and other respiratory issues (1.2%, n=1) (Table 1).

Table 1: Demographic Characteristics of Study Participants (n=86)

Characteristic	n	%
Age group		
18–24 years	48	55.8
25–30 years	32	37.2
31–35 years	6	7.0
Mean age (SD)	24.8 (3.9) years	
Gender		
Male	86	100
Female	0	0
Medical history		
None/Other	78	90.7
Allergies	4	4.7
Asthma	2	2.3
Cardiac conditions	1	1.2
Respiratory issues	1	1.2

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Dental Caries Prevalence and Severity

The mean DMFT score among e-cigarette users was 5.9 (SD 4.2), ranging from 0 to 15, with a median value of 5.0. Analysis of individual components revealed that the filled component contributed most substantially to the overall score (mean 2.4, SD 2.3), followed by decayed teeth (mean 2.3, SD 2.1), while missing teeth contributed least (mean 1.2, SD 1.4). The distribution of caries experience demonstrated that 16.3% of participants were caries-free (DMFT=0), 34.9% exhibited moderate caries levels (DMFT 4–7), and 32.6% manifested a high caries burden (DMFT ≥8) (Table 2).

Table 2: Mean DMFT and Components Among E-cigarette Users (n=86)

Component	Mean	SD	Median	Range
Decayed (D)	2.3	2.1	2.0	0–9
Missing (M)	1.2	1.4	1.0	0–4
Filled (F)	2.4	2.3	2.0	0–11
DMFT Total	5.9	4.2	5.0	0–15

Patterns of Electronic Cigarette Use

The mean duration of e-cigarette use was 3.1 years (SD 1.6), with the largest proportion reporting 3–4 years of use (34.9%), followed by ≥5 years (30.2%), 1–2 years (25.6%), and less than 1 year (9.3%). The majority of participants (68.6%) reported constant daily use, while 20.9% reported occasional use (5–10 times/day). Pod systems were the most commonly utilized devices (55.8%), followed by mod systems (44.2%). Nicotine concentration ranged from 0% to 50%, with a mean of 18.6% (SD 17.6%) and median of 5%; the largest group (40.7%) employed low nicotine concentrations (1–5%). Mixed flavors were most preferred (39.5%), followed by fruit-only (32.6%), mint-only (16.3%), and tobacco-only (11.6%). More than half of participants (52.3%) reported vaping within one hour preceding bedtime (Table 3).

Table 3: Patterns of Electronic Cigarette Use Among Participants (n=86)

Characteristic	Category	n	%
Duration of use	<1 year	8	9.3
	1–2 years	22	25.6
	3–4 years	30	34.9
	≥5 years	26	30.2
Frequency of use	Constant daily	59	68.6
	Occasional (5–10/day)	18	20.9
	Former user	6	7.0
	Rare (<5/day)	3	3.5
Device type	Pod system	48	55.8
	Mod system	38	44.2
Nicotine strength	0%	1	1.2
	1–5%	35	40.7
	6–20%	28	32.6
	30–50%	22	25.6
Flavor preference	Mixed (fruit+mint/tobacco)	34	39.5
	Fruit only	28	32.6
	Mint only	14	16.3
	Tobacco only	10	11.6
Bedtime vaping	Yes (within 1 hour)	45	52.3
	No	41	47.7

Association Between Vaping Patterns and DMFT Scores

A statistically significant increase in DMFT scores was observed with extended duration of e-cigarette use. Participants utilizing e-cigarettes for less than 2 years demonstrated a mean DMFT of 3.2 (SD 2.5), compared to 5.8 (SD 3.4) for 2–4 years, and 7.1 (SD 4.1) for ≥5 years ($F(2,83) = 10.23$, $p<0.001$). Constant daily users exhibited significantly higher DMFT scores (6.8, SD 4.0) compared to occasional/former users (3.8, SD 3.1; $t(84)=3.21$, $p=0.002$). No significant difference was observed between pod and mod system users (6.1 vs. 5.7, $p=0.65$). Higher nicotine concentrations were associated with increased DMFT scores, with <6% showing a mean DMFT of 4.9 (SD 3.6), 6–20% showing 5.9 (SD 4.0), and ≥30% showing 7.5 (SD 4.7; $F(2,83)=3.45$, $p=0.038$). No significant association emerged between flavor preference and DMFT ($F(3,82)=1.52$, $p=0.21$). Participants who vaped within one hour before bedtime had significantly higher DMFT scores (7.0, SD 4.2) compared to those who did not (4.8, SD 3.8; $t(84)=2.42$, $p=0.018$) (Table 4).

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Table 4: Mean DMFT by Vaping Patterns and Clinical Parameters

Variable	Category	n	Mean DMFT	SD	p-value
Duration	<2 years	30	3.2	2.5	<0.001*
	2–4 years	30	5.8	3.4	
	≥5 years	26	7.1	4.1	
Frequency	Constant daily	59	6.8	4.0	0.002**
	Occasional/Former	27	3.8	3.1	
Device	Pod system	48	6.1	4.3	0.65*****
	Mod system	38	5.7	4.0	
Nicotine	<6%	36	4.9	3.6	0.038*
	6–20%	28	5.9	4.0	
	≥30%	22	7.5	4.7	
Flavor	Mixed	34	6.2	4.3	0.21***
	Fruit only	28	6.0	4.0	
	Mint only	14	5.5	3.8	
	Tobacco only	10	5.3	4.1	
Bedtime vaping	Yes	45	7.0	4.2	0.018**
	No	41	4.8	3.8	
Saliva status	Normal	25	4.4	3.5	0.025*
	Reduced	35	6.5	4.0	
	Xerostomia	15	7.2	4.5	
Gingival status	Healthy	34	4.5	3.6	0.009**
	Gingivitis	40	6.8	4.0	
Plaque index	Low	35	5.0	3.8	0.13***
	Moderate	40	6.5	4.2	
	High	5	7.4	4.5	

*One-way ANOVA; **Independent t-test; ***Not significant; ****t-test*

Multivariate Linear Regression Analysis

Multiple linear regression analysis identified independent predictors of DMFT scores. The model incorporated age, duration of vaping, frequency of use (constant vs. other), nicotine strength (≥30% vs. <30%), and vaping before bedtime (yes vs. no). The overall model was statistically significant ($F(5,80)=14.7$, $p<0.001$), explaining 48% of the variance in DMFT scores ($R^2=0.48$; adjusted $R^2=0.45$). Duration of vaping emerged as the strongest independent predictor ($\beta=0.48$, $p<0.001$), with each additional year associated with a 0.89 increment in DMFT score. Constant use ($\beta=0.21$, $p=0.025$), high nicotine strength ($\beta=0.19$, $p=0.019$), and bedtime vaping ($\beta=0.18$, $p=0.047$) also demonstrated significant predictive capacity. Age was not significantly associated with DMFT ($p=0.43$) (Table 5).

Table 5: Multiple Linear Regression for DMFT Score (n=86)

Variable	B (coefficient)	95% CI	Standardized β	p-value
Age (years)	0.08	-0.12–0.28	0.07	0.43
Duration of vaping (years)	0.89	0.48–1.30	0.48	<0.001
Frequency (constant vs. other)	1.95	0.25–3.65	0.21	0.025
Nicotine strength (≥30% vs. <30%)	1.80	0.30–3.30	0.19	0.019
Vaping before bedtime (yes vs. no)	1.55	0.02–3.08	0.18	0.047
Constant	-1.50	-4.40–1.40	—	0.31

Model summary: $R = 0.69$, $R^2 = 0.48$, Adjusted $R^2 = 0.45$, $F(5, 80) = 14.7$, $p < 0.001$

Discussion

This investigation examined the association between electronic cigarette use and dental caries among Libyan young adults aged 18–35 years in Tripoli. The findings demonstrate that prolonged duration of use, constant daily consumption, elevated nicotine strength, and pre-bedtime vaping are independently associated with greater dental caries severity, with duration of use emerging as the predominant predictor. These results contribute to the growing body of evidence linking electronic cigarette use to adverse oral health outcomes and provide the first such data from the Libyan context.

The mean DMFT score of 5.9 (SD 4.2) observed in this study is notably higher than previously reported caries levels in Libyan populations, with 32.6% exhibiting a high caries burden (DMFT ≥8). Elamin et al. (2020) reported a mean dmft of 4.2 among 5-year-old Libyan children, while Huew et al. (2012) found DMFT scores ranging from 2.5 to 3.8 among Libyan schoolchildren

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(20,21). Although these studies involved different age groups, the elevated DMFT in this young adult sample (mean age 24.8 years) suggests that e-cigarette use may contribute to an accelerated caries trajectory. This finding is consistent with Khattak et al. (2024), who investigated oral health among 142 young adult e-cigarette users in Pakistan and reported a mean DMFT of 5.66 (SD 2.20), closely matching our finding (3). The similarity between these studies, conducted in disparate geographic contexts, strengthens the argument that e-cigarette use is consistently associated with elevated caries experience among young adults.

The distribution of DMFT components in our study—with filled teeth (2.4) and decayed teeth (2.3) contributing most substantially to the total score—indicates that while participants had some access to restorative care, ongoing cariogenic challenge persisted. This pattern is consistent with the conceptualization of dental caries as a dynamic disease process requiring continuous management (15). The high proportion of participants with gingivitis (46.5%) and xerostomia (17.4%) further supports the detrimental impact of vaping on oral tissues, consistent with previous findings (7,8,10).

Recent systematic reviews have examined this association with varying conclusions. Tabnjh et al. (2025) concluded that e-cigarette users may demonstrate higher prevalence of dental caries compared to non-smokers, noting that vaping may inhibit normal oral flora while enabling cariogenic bacterial proliferation (9). However, Cascaes et al. (2025) conducted a systematic review with meta-analysis and found that while there is a potential association between ENDS use and increased severity and risk of dental caries, the quantitative analysis of pooled effects showed no significant mean difference in caries history between ENDS users and non-users (MD: 0.72, 95% CI: -1.70 to 3.15), with the certainty of evidence rated as "very low" (1,5). The discrepancy between these findings and our observed associations may reflect differences in study design, outcome measurement, population characteristics, or the high risk of bias noted in most included studies.

The most robust finding was the strong dose-response relationship between duration of e-cigarette use and DMFT scores. Participants who vaped for ≥5 years had a mean DMFT of 7.1 compared to 3.2 among those vaping for <2 years. Multivariate regression confirmed each additional year of vaping independently increased DMFT by 0.89 units (β=0.48, $p<0.001$). This duration-response relationship constitutes a classic hallmark of causality in epidemiological research. This finding aligns with Tabnjh et al. (2025), who found that cumulative exposure to e-cigarette aerosol increases the risk of oral disease (9). Camoni et al. (2023) similarly noted in their systematic review that flavored e-liquids may constitute a caries risk factor, and comprehensive smoking counseling should investigate the type of habit in terms of duration and nicotine percentage (4).

Constant daily use was reported by 68.6% of participants and was associated with a mean DMFT of 6.8 compared to 3.8 among occasional and former users ($p=0.002$). This frequency-dependent effect is biologically plausible, as each vaping episode introduces sweetened, acidic aerosol into the oral cavity. Frequent, repeated exposure prevents the oral cavity from returning to a neutral, protective state between episodes, analogous to the Stephan curve concept for sugar consumption in caries development (15). The predominance of daily use (68.6%) in our sample is consistent with global trends, with Khattak et al. (2024) finding that 66% of young adult e-cigarette users in Pakistan reported daily use (3).

Higher nicotine concentrations (≥30%) were significantly associated with increased DMFT scores (7.5 vs. 4.9 for <6%, $p=0.038$). This finding is relevant given the trend toward higher nicotine concentrations in contemporary e-cigarette devices. Nicotine exerts several oral health effects that may indirectly increase caries risk, including vasoconstriction reducing gingival blood flow and impairment of protective immune surveillance. Additionally, nicotine reduces salivary flow rate, compromising the mouth's natural defense mechanisms (23).

Participants who vaped within one-hour preceding bedtime had significantly higher DMFT scores (7.0 vs. 4.8, $p=0.018$). This novel finding carries important clinical implications. During sleep, salivary flow decreases naturally, reducing buffering capacity and clearance of cariogenic substrates (11,12). Vaping before sleep likely leaves residual sweetened acidic aerosol in the oral cavity throughout the night, prolonging the demineralization challenge. This is analogous to the well-documented risk of bedtime bottle feeding in early childhood caries (21).

The observed associations are supported by multiple biologically plausible mechanisms identified in the literature. Salivary dysfunction and xerostomia are well-documented consequences of e-cigarette use. The hygroscopic properties of propylene glycol and vegetable glycerin absorb water from oral tissues, reducing salivary flow and compromising the mouth's protective mechanisms (11,12). In our study, participants with xerostomia had significantly higher DMFT scores (7.2 vs. 4.4, $p=0.025$), supporting this mechanism. Direct chemical challenges from acidic e-liquids (pH 3–6) and fermentable sweeteners provide substrates for cariogenic bacteria while simultaneously demineralizing enamel (13–15). Tabnjh et al. (2025) found that vaping generates a viscous aerosol that promotes biofilm formation and microbial adhesion, and that depletion of gram-positive bacteria in the oral cavity may facilitate adhesion of *S. mutans* to enamel (9).

The high caries burden observed in this study is consistent with the general oral health situation in Libya. Huew et al. (2012) examined dental caries and its association with diet and dental erosion in Libyan schoolchildren, reporting caries prevalence of 41% among 12-year-olds, with higher rates among those with frequent between-meal snacking and limited access to dental care (21). Elamin et al. (2020) similarly reported that dental caries prevalence among Libyan children was 67% with a mean dmft of 3.5, and identified significant associations with sugar consumption and oral hygiene practices (20). These studies highlight that baseline caries risk in the Libyan population is already substantial, and e-cigarette use may compound these existing risk factors. The absence of a non-user control group in our study limits direct comparison with

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non-vapers in the Libyan population; however, the general population caries burden in Libya is exceptionally high, suggesting that e-cigarette use may further exacerbate oral health disparities.

Dental clinicians should routinely inquire about e-cigarette use, including duration, frequency, nicotine strength, and bedtime utilization. E-cigarette use should be considered a risk factor for dental caries, particularly among young adults. Targeted preventive counseling should be provided, and more frequent recall intervals (e.g., 4–6 months) may benefit high-risk users. Prescription of high-concentration fluoride toothpaste (5000 ppm) or in-office fluoride varnish applications should be considered for e-cigarette users with active caries or xerostomia. Public health policy in Libya should consider public awareness campaigns specifically addressing oral health risks of e-cigarettes, regulation of e-liquid flavorings and nicotine concentrations, and inclusion of oral health warnings on e-cigarette packaging (1,20,21).

Strengths and Limitations

Strengths include comprehensive assessment of e-cigarette use patterns, standardized outcome measurement using the DMFT index, clinical examination by a dental professional, and multivariate analysis adjusting for multiple potential confounders. This is the first study to investigate the association between e-cigarette use and dental caries in the Libyan population, providing baseline data for future research.

The cross-sectional design cannot establish temporality or causation. All participants were male, limiting generalizability to females. The convenience sampling method may not be representative of all e-cigarette users in Tripoli. The small sample size (n=86) limited statistical power for detecting small effect sizes. No assessment of conventional tobacco use or socioeconomic status was conducted.

Conclusions

This investigation demonstrates that among Libyan male e-cigarette users, prolonged duration, constant daily use, elevated nicotine strength, and pre-bedtime vaping are independently associated with heightened caries severity, with duration of use emerging as the strongest predictor. These findings underscore the need for dental clinicians to routinely assess e-cigarette use and implement targeted preventive interventions.

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