



Current electronic cigarette use and untreated coronal caries in United States adults: a cross-sectional study

Uso actual de cigarrillos electrónicos y caries coronal no tratada en adultos de Estados Unidos: estudio transversal

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ABSTRACT

Introduction: Untreated coronal caries is common among adults in the United States, and electronic cigarette use has increased. Evidence on whether e-cigarette use is associated with untreated caries independently of combustible tobacco is limited. **Methods:** Cross-sectional analysis of pooled 2015-2016 and 2017-2018 National Health and Nutrition Examination Survey data from 9,042 dentate adults aged 20 years or older. Current e-cigarette use was defined as use in the past 30 days; untreated coronal caries was defined as at least one permanent tooth with untreated decay. Survey-weighted logistic regression with Taylor series linearization estimated odds ratios, adjusting for sociodemographic factors, combustible tobacco use and dental visits. **Results:** Weighted prevalence was 5.50% for current e-cigarette use and 19.20% for untreated coronal caries (30.20% among users and 18.50% among non-users). The odds ratio was 1.91 (95% CI 1.47-2.48) unadjusted and 1.64 (95% CI 1.23-2.19) after adjustment for age, sex and race/ethnicity. After full adjustment for education, income, cigarette smoking, cigar use and dental visits, the association was no longer evident (OR 0.98, 95% CI 0.76-1.27). **Conclusions:** The higher prevalence of untreated coronal caries among e-cigarette users was explained by combustible tobacco use and sociodemographic and dental-access factors; current e-cigarette use was not independently associated with untreated coronal caries in United States adults.

Keywords: electronic nicotine delivery systems; dental caries; adult; cigarette smoking; cross-sectional studies; nutrition surveys.

RESUMEN

Introducción: La caries coronal no tratada es frecuente en los adultos de Estados Unidos y el uso de cigarrillos electrónicos ha aumentado. La evidencia sobre su asociación con caries no tratada, independiente del tabaco combustible, es limitada. **Métodos:** Análisis transversal de los datos combinados de la National Health and Nutrition Examination Survey 2015-2016 y 2017-2018 de 9042 adultos dentados de 20 años o más. El uso actual de cigarrillos electrónicos se definió como uso en los últimos 30 días; la caries coronal no tratada, como al menos un diente permanente con caries no tratada. Se estimaron odds ratios con regresión logística ponderada y linealización de Taylor, ajustando por factores sociodemográficos, tabaco combustible y visitas odontológicas. **Resultados:** Las prevalencias ponderadas fueron 5,50% para uso actual de cigarrillos electrónicos y 19,20% para caries coronal no tratada (30,20% en usuarios y 18,50% en no usuarios). La odds ratio fue 1,91 (IC 95% 1,47-2,48) sin ajustar y 1,64 (IC 95% 1,23-2,19) tras ajustar por edad, sexo y raza/etnia. Tras ajustar además por educación, ingresos, tabaquismo, uso de cigarros y visitas odontológicas, la asociación dejó de ser evidente (OR 0,98, IC 95% 0,76-1,27). **Conclusiones:** La mayor prevalencia de caries coronal no tratada en usuarios de cigarrillos electrónicos se explicó por el tabaco combustible y por factores sociodemográficos y de acceso odontológico; el uso actual de cigarrillos electrónicos no se asoció de forma independiente con caries coronal no tratada en adultos de Estados Unidos.

Palabras clave: sistemas electrónicos de liberación de nicotina; caries dental; adulto; fumar cigarrillos; estudios transversales; encuestas nutricionales.

INTRODUCTION

Dental caries is the most prevalent noncommunicable disease worldwide, and the global burden of untreated caries in permanent teeth is larger than that of any other oral condition.(1) The condition affects permanent teeth across the life course and, when untreated, progresses to pain, infection and ultimately tooth loss, which is why its presence is measured separately from treated disease in surveillance systems.(1,2) The disease results from a prolonged imbalance between demineralization and remineralization of the tooth surface, driven mainly by fermentable carbohydrates and mediated by acidogenic biofilms.(1,3) Untreated coronal caries, the clinical endpoint of this process, indicates disease that has not been arrested or restored and therefore signals unmet dental need. In the United States, untreated coronal caries is distributed unevenly, with substantially higher prevalence among adults with low income, low educational attainment and infrequent dental attendance.(4) Untreated lesions are the direct target of population oral health surveillance because they represent disease that could have been prevented or treated, and they correlate closely with self-reported oral health problems and with subsequent tooth loss.(1,4) Caries management has moved toward risk assessment and minimally invasive care, yet untreated lesions remain a persistent marker of oral health inequity.(2) Identifying the modifiable exposures that cluster among adults with untreated caries is therefore a prerequisite for targeting prevention.

Electronic cigarettes entered the United States market in the late 2000s, and both awareness and use expanded rapidly over the following decade.(5,6) By 2019, e-cigarettes were the most commonly used non-cigarette tobacco product among United States adults, with a current-use prevalence of 4.5%, concentrated in adults aged 18 to 24 years.(7) The preceding year, current e-cigarette use among adults was estimated at 3.2%, which illustrates the rapid growth of the exposure within the study window.(8) A large share of e-cigarette users also smoke combustible cigarettes: among current e-cigarette users in 2019, roughly one third were current cigarette smokers, a pattern of dual use that complicates any attempt to attribute oral outcomes to one product rather than the other.(7) State and local regulation of e-cigarettes was also associated with use patterns during this period, so the population of users changed quickly.(9) Comparable exposure patterns have been documented in national surveys outside the United States, where e-cigarette use is likewise highest in younger adults.(10) E-cigarette use is also strongly patterned by smoking history: current use is concentrated in current and former cigarette smokers, while exclusive use without any combustible smoking is more common in younger cohorts.(6,7) This overlap between vaping and smoking is central to the present analysis, because any study that ignores cigarette smoking risks attributing the well-known oral consequences of combustible tobacco to e-cigarettes.

Combustible tobacco is itself an established risk factor for oral disease, and this fact is central to interpreting any study of e-cigarettes. Meta-analytic evidence links cigarette smoking with a higher prevalence of dental caries, and smoking reshapes the supragingival microbiome in ways that favor cariogenic communities.(11,12) Smoking is also associated with xerostomia and with less frequent dental attendance, two pathways that connect tobacco use to untreated disease.(13) Because e-cigarette use so often coexists with cigarette smoking, an analysis that fails to separate the two products cannot establish whether any observed association is attributable to e-cigarettes or to the combustible tobacco with which they overlap.

Several lines of evidence suggest that e-cigarettes could promote dental caries. E-liquids frequently contain sweet flavorings, and laboratory work shows that sweet-flavored aerosols increase the cariogenic potential of tooth surfaces and that e-cigarette vapor promotes *Streptococcus mutans* growth, adhesion and biofilm formation in vitro.(14,15) Nicotine delivery may also reduce salivary flow, and a reduced saliva-mediated buffer is a recognized contributor to caries risk.(13) Clinical reports and reviews have described elevated caries risk among people who vape, and systematic reviews conclude that the oral health effects of electronic nicotine delivery systems are plausible but not yet firmly established.(16-19) The most directly comparable population study, an analysis of the 2017-2018 National Health and Nutrition Examination Survey, reported higher odds of untreated caries among current e-cigarette users, but it used never smokers as the reference group and did not fully separate e-cigarette exposure from combustible tobacco use.(20) It therefore remains unclear whether the observed association reflects a specific effect of e-cigarettes or confounding by combustible tobacco and by the sociodemographic and dental-access characteristics that distinguish e-cigarette users from non-users. From a clinical standpoint, resolving this question matters for risk assessment and for the counseling that dental teams provide, since vaping status is increasingly recorded in dental histories and used to stratify patients by caries risk.(17,20) If the association is largely explained by smoking and access, the appropriate preventive target is different from what it would be if the aerosol itself were cariogenic.

This study distinguished a primary outcome, untreated coronal caries defined as at least one untreated decayed permanent tooth, from a secondary outcome, the number of untreated decayed teeth, and from prespecified exploratory subgroup analyses. This hierarchy followed the analytic plan so that the confirmatory estimate, the fully adjusted odds ratio for the primary outcome, was defined before the results were inspected and analyzed. The objective was to estimate the association between current e-cigarette use and untreated coronal caries in a nationally representative sample of United States adults, independent of combustible tobacco use and sociodemographic factors. The hypothesis was that current e-cigarette use would be associated with a higher prevalence of untreated coronal caries after these adjustments.

METHODS

Design and data source

This cross-sectional study analyzed public-use files from two pooled cycles, 2015-2016 and 2017-2018, of the National Health and Nutrition Examination Survey (NHANES), a stratified multistage probability sample of the non-institutionalized United States civilian population.⁽²¹⁾ The demographics, oral health dentition examination, smoking and cigarette use, and oral health questionnaire files were downloaded programmatically from the Centers for Disease Control and Prevention. NHANES combines an in-home interview with standardized physical and oral examinations performed in mobile examination centers, and its complex sampling design produces nationally representative estimates when the supplied examination weights and masked variance units are applied.⁽²¹⁾ The two cycles were pooled to increase sample size and to cover a period, 2015 through 2018, during which e-cigarette use expanded rapidly among United States adults.⁽⁷⁾ Each cycle is an independent, nationally representative sample, so pooling them required the construction of combined weights and combined variance units rather than a simple concatenation of records.

The oral health component of the examination is performed by trained dental examiners using a standardized protocol that records, tooth by tooth, the presence and coronal status of each permanent tooth.⁽²¹⁾ The examination is conducted in the mobile examination center, and the corresponding examination weights account for non-response and for the differential probabilities of selection produced by the oversampling of specific demographic groups.⁽²¹⁾ The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies. Because the data are fully de-identified and publicly available, no ethical approval was required, and no identifying information was accessed.

Study population

Adults aged 20 years or older who completed the oral health examination and had at least one natural permanent tooth were eligible. Participants younger than 20 years were excluded because educational attainment is not recorded in a comparable way at younger ages. Edentulous adults were excluded because they cannot have coronal caries, and adults without a performed oral health examination were excluded. The analytic sample was further restricted to participants with complete data on e-cigarette use, cigarette smoking, covariates and the caries examination, following a complete-case approach; participants with missing values on any analytic variable were dropped.

Variables

The primary outcome was untreated coronal caries, defined as at least one permanent tooth among teeth 2 to 15 and 18 to 31, excluding third molars, with a coronal caries status of Z in the NHANES dentition examination. The status Z identifies a permanent tooth with a dental carious surface condition, that is, a tooth with untreated decay. Third molars were excluded because they are absent or unerupted in a large proportion of adults and are not consistently scored in the caries assessment. The secondary outcome was the number of untreated decayed permanent teeth, ranging from 0 to 28, obtained by counting teeth with that same status code; this variable captures the severity of untreated disease rather than its mere presence.

Current e-cigarette use, the exposure, was defined as self-reported use of an e-cigarette on at least one day in the past 30 days. This definition corresponds to the standard population measure of current use employed in national surveillance.⁽⁷⁾ Participants who had never used e-cigarettes, or who had not used them in the past 30 days, formed the reference group. The 30-day window was

chosen over the alternative 5-day window because it is the measure used in surveillance reports and because it captures intermittent as well as daily users, reducing misclassification of occasional use. Covariates were age in years, sex, race and Hispanic origin (Hispanic, non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and other or multiracial), education (less than high school, high school or equivalent, some college, and college graduate or above), family income-to-poverty ratio, cigarette smoking status, current cigar use in the past 30 days, current smokeless tobacco use in the past 30 days, and dental visit within the past year. Covariates were age in years, sex, race and Hispanic origin (Hispanic, non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, and other or multiracial), education (less than high school, high school or equivalent, some college, and college graduate or above), family income-to-poverty ratio, cigarette smoking status, current cigar use in the past 30 days, current smokeless tobacco use in the past 30 days, and dental visit within the past year. The income-to-poverty ratio was modeled as a continuous variable on its original zero-to-five scale. Cigarette smoking status was classified as never, former or current from the lifetime cigarette use and current smoking questions; this three-level variable was the principal combustible tobacco adjustment. Current cigar and smokeless tobacco use were derived from the number of days of use reported in the past 30 days and served to capture non-cigarette combustible and non-combustible nicotine exposure. The dental visit variable was dichotomized as a visit within the past year versus a visit more than one year ago or never, as a proxy for access to dental care. The dentition examination codes each tooth independently, which allowed the primary and secondary outcomes to be derived from the same tooth-level data without relying on self-report of caries status.

Statistical analysis

A combined four-year mobile examination center weight was computed as the two-year examination weight divided by two, following the standard procedure for pooling two NHANES cycles. For variance estimation the masked variance pseudo-stratum was made unique to each cycle and the masked variance pseudo-primary sampling unit was used as the cluster, so that the two cycles contributed distinct design units. All point estimates and standard errors were computed with Taylor series linearization for stratified cluster samples, implemented in Python; this estimator is the survey-design analogue of the sandwich estimator and accounts for the clustering and stratification of the NHANES design without assuming simple random sampling. Weighted means and proportions with 95% confidence intervals described the analytic sample, and weighted contrasts compared current e-cigarette users with non-users.

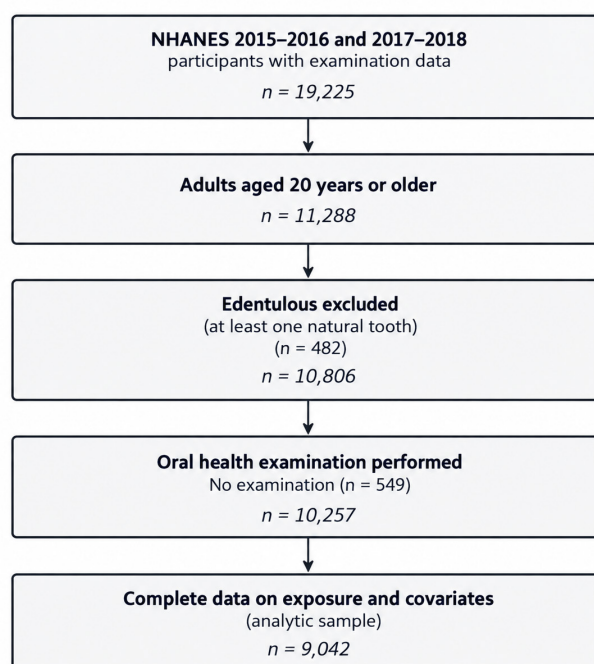
The association between current e-cigarette use and untreated coronal caries was estimated with survey-weighted logistic regression, which estimates odds ratios for this common binary outcome. Model 1 was unadjusted. Model 2 added age, sex and race/ethnicity. Model 3, the primary model, added education, income-to-poverty ratio, cigarette smoking status, current cigar use and dental visit within the past year; cigarette smoking status was the central combustible tobacco adjustment specified by the study question, and the remaining covariates addressed socioeconomic position and access to care, the two other candidate confounders identified in the literature. (4,20) Two sensitivity analyses were prespecified: restriction to adults aged 20 to 64 years, to assess whether inclusion of older adults, among whom e-cigarette use is rare, influenced the estimate, and additional adjustment for current smokeless tobacco use, to test whether other nicotine products explained any residual association. Exploratory analyses estimated the association within strata of age group and cigarette smoking status and tested interaction terms between e-cigarette use and each of those variables in the fully adjusted model. Two-sided tests used an alpha of 0.05, and 95% confidence intervals are reported throughout. The secondary outcome, the number of untreated decayed teeth, was summarized with weighted means because its distribution was skewed, and the means were compared descriptively between exposure groups rather than modeled with a count regression. Analyses were performed in Python 3.14 with pandas, numpy and scipy using a purpose-written Taylor series linearization estimator; the analysis script is reproducible and the computed metrics are stored with the manuscript. The same script was executed twice on the same data and produced identical results, which verified that the estimates were not affected by any stochastic components.

RESULTS

Study population

The pooled NHANES 2015-2018 sample comprised 19,225 participants, of whom 11,288 were aged 20 years or older (Figure 1). The two survey cycles contributed comparable numbers of adults. After excluding 482 edentulous adults and 549 adults without a performed oral health examination, 10,257 dentate adults remained. Of these, 9,042 had complete data on exposure, covariates and caries and formed the analytic sample; the remainder were excluded because one or more analytic variables were missing.

Figure 1. Flow diagram of participant selection from the pooled NHANES 2015-2018 adult sample.



Note: NHANES = National Health and Nutrition Examination Survey. Source: Own elaboration.

Current e-cigarette users differed from non-users across sociodemographic and behavioral characteristics (Table 1). A larger proportion of users than of non-users were male, were current cigarette smokers, and reported current cigar or smokeless tobacco use. Users were younger, had a lower mean income-to-poverty ratio, and a smaller proportion reported a dental visit within the past year. Current e-cigarette use was concentrated in adults aged 20 to 39 years and in current cigarette smokers. The mean number of untreated decayed teeth was also higher in e-cigarette users than in non-users (Table 1).

Primary outcome

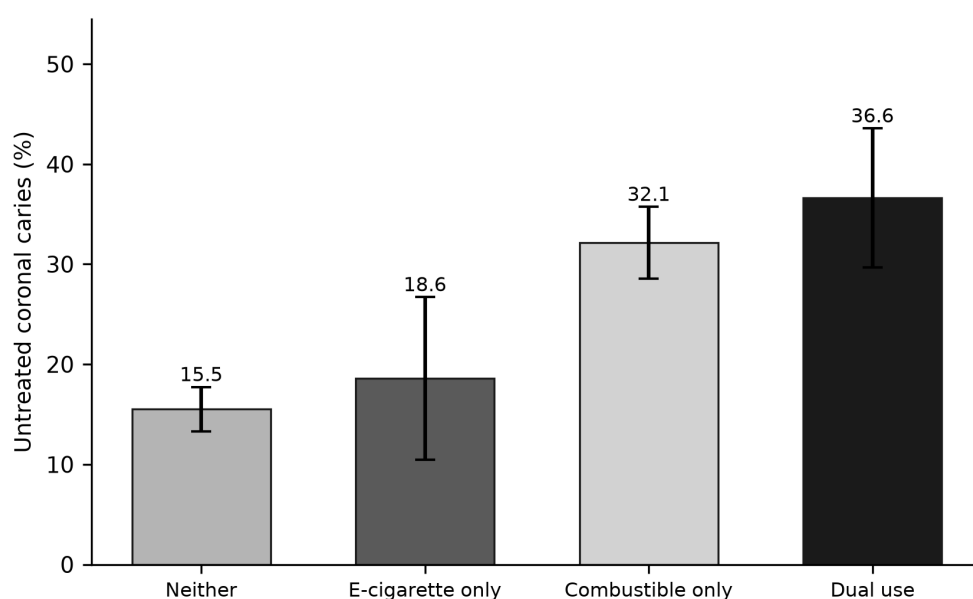
The weighted prevalence of current e-cigarette use was 5.50%, based on 417 users, and the weighted prevalence of untreated coronal caries was 19.20% overall, based on 2,071 affected adults. Untreated coronal caries was more prevalent among current e-cigarette users than among non-users, at 30.20% versus 18.50% (Table 2). The prevalence also rose with cigarette smoking status, from the lowest value in never smokers to the highest value in current smokers, a gradient consistent with the combined-category pattern described below.

Prevalence rose across combined tobacco use categories, from 15.50% among adults who used neither product to 18.60% among exclusive e-cigarette users, 32.10% among exclusive combustible tobacco users and 36.60% among dual users (Figure 2). The highest prevalence was observed among adults who used both product types, and the prevalence among exclusive e-cigarette users was closer to the prevalence among users of neither product than to the prevalence among combustible tobacco users.

Table 1. Characteristics of US adults aged 20 years and older by current e-cigarette use, NHANES 2015-2018.

Characteristic	All (n = 9042)	No e-cigarette (n = 8625)	E-cigarette (n = 417)	p
Age, mean (SD)	47.9 (17.1)	48.5 (17.1)	37.3 (14.5)	<0.001
Age 20-39	36.5	35.0	62.2	<0.001
Age 40-64	43.6	44.2	33.9	<0.001
Age 65 or more	19.9	20.9	3.9	<0.001
Male	48.1	47.4	60.4	<0.001
Female	51.9	52.6	39.6	<0.001
Hispanic	14.3	14.5	11.3	0.030
Non-Hispanic White	65.1	65.0	66.9	0.538
Non-Hispanic Black	11.0	11.0	10.5	0.657
Non-Hispanic Asian	5.4	5.5	2.6	<0.001
Other/multiracial	4.2	4.0	8.7	0.017
Less than high school	12.0	11.6	17.4	0.003
High school or equivalent	23.9	23.3	34.6	<0.001
Some college	32.0	31.8	36.6	0.072
College graduate or above	32.1	33.3	11.4	<0.001
Income-to-poverty ratio, mean (SD)	3.0 (1.6)	3.1 (1.6)	2.5 (1.6)	<0.001
Never smoker	57.1	59.5	15.9	<0.001
Former smoker	25.5	25.5	26.8	0.603
Current smoker	17.4	15.1	57.3	<0.001
Current cigar use	6.1	5.1	23.7	<0.001
Current smokeless tobacco use	3.7	3.2	10.6	<0.001
Dental visit within past year	59.1	59.7	48.0	<0.001
Untreated decayed teeth, mean (SD)	0.5 (1.5)	0.5 (1.5)	1.1 (2.6)	<0.001

Note: Values are weighted percentages or weighted mean (SD). p values are from survey-weighted linear contrasts with Taylor series linearization. Source: Own elaboration from the National Health and Nutrition Examination Survey (NHANES) 2015-2018.

Figure 2. Weighted prevalence of untreated coronal caries by tobacco use category.

Note: Error bars indicate 95% confidence intervals. E-cigarette and combustible tobacco use refer to the past 30 days. Source: Own elaboration.

Table 2. Weighted prevalence of untreated coronal caries by e-cigarette use and cigarette smoking status, NHANES 2015-2018.

Group	Prevalence (%)
Overall	19.2
Current e-cigarette use	30.2
No current e-cigarette use	18.5
Never smoker	15.7
Former smoker	16.4
Current smoker	34.7

Note: Untreated coronal caries was defined as at least one permanent tooth with untreated decay. Source: Own elaboration from the National Health and Nutrition Examination Survey (NHANES) 2015-2018.

In survey-weighted logistic regression, the unadjusted odds of untreated coronal caries were 1.91 times higher (95% CI 1.47-2.48) among current e-cigarette users than among non-users (Table 3). Adjustment for age, sex and race/ethnicity attenuated the estimate to 1.64 (95% CI 1.23-2.19). After full adjustment for education, income-to-poverty ratio, cigarette smoking status, cigar use and dental visits, the association was no longer evident, with an odds ratio of 0.98 (95% CI 0.76-1.27).

Secondary outcome

The weighted mean number of untreated decayed teeth was 0.52 overall, 1.15 among current e-cigarette users and 0.49 among non-users (Table 1). The mean was higher in e-cigarette users than in non-users.

Table 3. Association between current e-cigarette use and untreated coronal caries, survey-weighted logistic regression.

Model	OR	95% CI	p
Unadjusted	1.91	1.47-2.48	<0.001
Adjusted for age, sex and race/ethnicity	1.64	1.23-2.19	<0.001
Fully adjusted	0.98	0.76-1.27	0.896
Sensitivity: adults aged 20-64 years	0.99	0.78-1.27	0.963
Sensitivity: additionally adjusted for smokeless tobacco	0.96	0.74-1.24	0.744

Note: OR = odds ratio; CI = confidence interval. The fully adjusted model includes age, sex, race/ethnicity, education, income-to-poverty ratio, cigarette smoking status, current cigar use and dental visit within the past year. Source: Own elaboration from the National Health and Nutrition Examination Survey (NHANES) 2015-2018.

Sensitivity and exploratory analyses

The primary result was stable in sensitivity analyses. Restricting the sample to adults aged 20 to 64 years produced an odds ratio of 0.99 (95% CI 0.78-1.27), and additional adjustment for current smokeless tobacco use produced an odds ratio of 0.96 (95% CI 0.74-1.24) (Table 3).

In subgroup analyses the fully adjusted odds ratio was 1.13 (95% CI 0.83-1.55) among adults aged 20 to 39 years, 0.85 (95% CI 0.55-1.32) among those aged 40 to 64 years and 0.39 (95% CI 0.07-2.02) among those aged 65 years or older. By cigarette smoking status the odds ratio was 1.02 (95% CI 0.56-1.84) in never smokers, 0.85 (95% CI 0.37-1.92) in former smokers and 0.97 (95% CI 0.71-1.33) in current smokers. The interaction of e-cigarette use with age group and with cigarette smoking status was not statistically significant ($p = 0.128$ and $p = 0.977$, respectively). None of the subgroup point estimates departed from the null by a meaningful margin, and the subgroup in which the exposure is least common, adults aged 65 years or older, had the widest confidence interval.

DISCUSSION

In this nationally representative sample of United States adults, current e-cigarette users had a higher prevalence of untreated coronal caries than non-users, but the association disappeared once combustible tobacco use and sociodemographic and dental-access factors were taken into account. The crude odds ratio of 1.91 fell to 1.64 with demographic adjustment and to 0.98, close to the null, in the fully adjusted model. This pattern indicates that the elevated caries prevalence observed among e-cigarette users is explained largely by their concurrent cigarette smoking and by the socioeconomic and dental-care characteristics that accompany e-cigarette use, rather than by an independent effect of the aerosol itself.

These findings refine the emerging literature on vaping and caries. Vemulapalli and colleagues, analyzing the 2017-2018 NHANES, reported higher odds of untreated caries among current e-cigarette users, but their reference group was never smokers, so their estimate could not distinguish an e-cigarette effect from combustible tobacco exposure.(20) A clinic-based study of more than 13,000 patients likewise found a higher caries risk level among people who vaped, although it relied on record-based risk assessment and did not control for smoking and socioeconomic position in the same way.(17) The present analysis, which explicitly adjusted for cigarette smoking status and other combustible tobacco, is consistent with the direction of those earlier reports in unadjusted terms but attributes the excess risk to confounding. Scoping and systematic reviews have repeatedly concluded that the evidence linking e-cigarettes to caries is suggestive rather than conclusive, a caveat that this result supports.(18,19,22,23)

The discrepancy with earlier reports is best understood through the composition of the e-cigarette-using population. In this sample, more than half of e-cigarette users were current cigarette smokers, and a further quarter were former smokers, so the group carried a heavy burden of combustible tobacco exposure that is itself an established caries risk factor.(11) When the combined categories were examined, untreated caries prevalence rose from 15.50% among users of neither product to 32.10% among combustible tobacco users and 36.60% among dual users, while exclusive e-cigarette users had a prevalence close to that of users of neither product. This gradient, in which combustible tobacco drives most of the excess, mirrors the demographic pattern described in national surveillance, where a large share of e-cigarette users also smoke cigarettes.(7) It also explains why studies that compare e-cigarette users with never smokers, without separating dual use, observe associations that attenuate once combustible tobacco is entered into the model.(20)

The mechanistic literature offers reasons why an independent association might exist but also why it could be modest. Sweet e-liquid flavorings increase the cariogenic potential of aerosols, and e-cigarette vapor promotes *Streptococcus mutans* growth, adhesion and biofilm formation in vitro.(14,15) E-cigarette users show compositional shifts in the supragingival and salivary microbiome that resemble, in part, the shifts described in combustible tobacco users, and aerosol exposure has broad effects on the oral environment.(24,25) However, combustible tobacco has a well-documented association with dental caries,(11) and smoking alters the supragingival microbiome in ways directly relevant to caries.(12) Because a majority of e-cigarette users in this sample also smoked cigarettes, the independent contribution of vaping to caries, if any, is difficult to detect above the strong signal of combustible tobacco. Xerostomia and reduced salivary buffering, proposed intermediaries between vaping and caries, are reported for e-cigarette use but are less pronounced than with smoking, and the toxicological evidence indicates that, although e-cigarette aerosol is not harmless, its oral burden is lower than that of combustible smoke.(13,26)

The same pattern of attenuation appears in the periodontal literature. A national study of Korean adults reported associations between e-cigarette use and periodontal disease that weakened markedly once conventional cigarette smoking was accounted for.(27) The parallel between that result and the present one suggests that, at least in populations where vaping and smoking overlap heavily, unadjusted oral disease estimates for e-cigarettes overstate any product-specific effect. This is not to say that e-cigarettes are benign for the oral cavity; it means that, in cross-sectional data with substantial dual use, their independent signal is smaller than the signal of the combustible tobacco with which they co-occur.

An important caveat is that the failure to detect an independent association should not be read as definitive proof that e-cigarette aerosols cannot promote caries. The analytic sample contained 417 current e-cigarette users, and the fully adjusted confidence interval of 0.76-1.27 could not exclude a modest association. If an independent effect exists but is small, it would require larger samples or better-separated exposure groups to detect. In vitro data show that sweetened aerosols can be cariogenic,(14) so the appropriate conclusion is that any independent effect in the general adult population is modest relative to combustible tobacco and to diet and access, not

that the mechanism is irrelevant.

Diet and oral hygiene are the dominant proximal determinants of coronal caries and may further explain the null independent result. Dietary patterns and diet quality are associated with caries in United States adults, and untreated caries is strongly patterned by income, education and dental attendance.(4,28,29) In this sample e-cigarette users reported fewer dental visits, a known correlate of untreated disease, and lower income, which supports the interpretation that access and behavior, rather than the aerosol itself, account for the observed disparity.(30) Because e-cigarette users in this sample were also more often current cigarette smokers, the confounding was largely positive, inflating the crude estimate relative to the adjusted one; the attenuation seen across models is therefore the expected signature of confounding by tobacco use and access. International studies of adult caries confirm that untreated lesions track socioeconomic gradients even in populations with low e-cigarette use.(31) The ecological plaque model remains the reference framework for understanding how diet and salivary factors, rather than any single product, drive caries initiation.(3)

This study has strengths. It used a large, nationally representative sample with a standardized clinical examination, an exposure definition based on the past 30 days, and explicit adjustment for cigarette smoking, the principal confounder identified in earlier work. The prespecified hierarchy separated the primary outcome from secondary and exploratory analyses, and two sensitivity analyses produced estimates consistent with the primary model. The combined four-year design more than doubled the sample available to earlier single-cycle analyses and improved the precision of the subgroup estimates in younger adults, the group in which e-cigarette use is most common.(7) The use of masked variance units with a Taylor series linearization estimator respected the complex survey design rather than treating the sample as if it were a simple random sample, and the reporting of unadjusted, partially adjusted and fully adjusted models allowed the contribution of each covariate group to be traced as the estimate moved toward the null.

Several limitations require consideration. First, the design is cross-sectional, so temporality between e-cigarette use and caries cannot be established, and longitudinal studies would be needed to rule out reverse causation or shared antecedents; a cohort design that measures incident caries after documented e-cigarette initiation would be the most direct test. Second, exposure was self-reported and captured only the past 30 days, which may misclassify intermittent users, so future work would benefit from biomarker confirmation of exposure. Third, the recall windows of the tobacco questionnaires could not reconstruct lifetime duration or intensity of vaping, and cohort studies that measure cumulative exposure would strengthen causal inference. Fourth, diet and oral hygiene were not directly measured, leaving residual confounding, and a future analysis with dietary recall data could address this gap; sugar intake in particular is a strong determinant of coronal caries that NHANES measures only through separate dietary modules.(28) Fifth, because e-cigarette use is concentrated in young adults and among smokers, subgroup estimates, particularly in older adults, were imprecise, and larger pooled cycles would improve precision. Sixth, the complete-case approach excluded participants with missing data, and although the analytic sample remained large, a multiple-imputation analysis would test the sensitivity of the estimates to missingness. Seventh, the results apply to dentate adults in the United States and may not generalize to populations with different patterns of dual tobacco use or different caries epidemiology.(10,31)

For clinical practice, these findings do not diminish the importance of asking about vaping, because e-cigarette users in this sample carried a substantial burden of untreated caries and of combustible tobacco use. Dental teams can use vaping status as a marker of elevated caries risk and as an opening to address concurrent smoking, which remains the stronger and better-documented oral health threat. The finding that the association attenuates after adjustment also reinforces the value of a complete risk assessment that records smoking status, socioeconomic circumstances and dental attendance alongside vaping, since these factors jointly determine caries risk.(2,4) Public health messaging about the oral effects of e-cigarettes should avoid overstating an independent cariogenic effect while continuing to emphasize cessation of all tobacco products. The absence of an independent association in this population does not license complacency about e-cigarette marketing to young adults, whose initiation of any nicotine product carries its own risks.(7,9) Finally, because the exposure and the outcome are both measurable in routine dental and survey settings, the analytic approach used here can be replicated in other national surveys to monitor whether the association changes as the product market and dual-use patterns evolve over time.(10)

CONCLUSIONS

In this nationally representative sample of United States adults, current e-cigarette users had a higher prevalence of untreated coronal caries than non-users, but this excess was explained by combustible tobacco use and by sociodemographic and dental-access factors. After adjustment for these confounders, current e-cigarette use was not independently associated with untreated coronal caries, and the result was consistent across sensitivity analyses, age strata and cigarette smoking strata. The higher number of untreated decayed teeth observed among e-cigarette users followed the same pattern and was likewise attributable to concurrent combustible tobacco use and to the characteristics of the population that uses e-cigarettes.

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CONFLICT OF INTEREST

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