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Association between asthma and dental caries in US (United States) adult population

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ABSTRACT

Objective: To investigate the associations of asthma with dental-carries-experience (DFT: decayed and filled teeth) and untreated-dental-carries (DT: decayed teeth) in the US adult population.

Methods: Data from the National Health and Nutritional Examination Survey, 2009–2014 were analyzed. Study-participants were classified into current, former and never asthmatics based on their asthma-status. Former-asthmatics were excluded. Both the outcomes, dental-carries-experience and untreated-dental-carries were dichotomized as being either present or absent, and were also categorized into tertiles based on their distributions in our study-sample. Logistic regression analyses were performed to determine the associations of asthma with dichotomized outcomes. The generalized logit model was applied for multilevel categorical outcomes. Multivariable models were developed to control for common demographic, clinical, and lifestyle factors.

Results: Total study-participants were 13,135, representing 175.26 million US adults. In the adjusted models, current-asthmatics, when compared to the reference group of never-asthmatics, were more likely to have dental-carries-experience (odds ratio [OR], 1.37; 95% confidence interval [CI], 1.13–1.66) and untreated-dental-carries (OR, 1.38; 95% CI, 1.10–1.73) in ≥ 1 tooth. Asthma was associated with all three categories of dental-carries-experience in our study-sample. We observed a positive gradient in the OR with an increasing extent of untreated-dental-carries. Relative to never-asthmatics, asthma doubled the odds of having untreated dental caries in the subgroup of current-smokers.

Conclusion: Current-asthmatic adults had higher odds of dental-carries-experience and untreated-dental-carries as compared to never-asthmatic adults in the US. Based on the observations from this study, interprofessional collaboration should be recommended to institute caries control and health promotion in current-asthmatic adult population.

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Introduction

Dental caries, commonly known as tooth decay, is one of the most prevalent chronic diseases in the United States (1). It causes a tremendous socioeconomic impact and affects patients' quality of life (2,3). Not only does it affect children, it is also very common in adults (1,4). In the US, nearly one third of adults aged 20–44 years had untreated dental caries in one or more of their teeth (5). According to the Centers for Disease Control and Prevention (CDC), by age 34, more than

80% of people have had at least one cavity and more than 40% of adults felt pain in their mouth in the previous year (6). Although largely preventable (1), it remains an important public health problem.

Similar to dental caries, asthma is also a highly prevalent chronic inflammatory disease in the US which afflicts the health and lifestyle of those who are affected (7). Asthma affects the immune system, and hence may cause a disturbance in oral microbiota. Combined with anti-asthmatic medications, which

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modulate airway and systemic immune responses, this condition may increase the risk of dental caries (8). Mouth breathing that may be more prevalent in asthmatic patients, particularly with co-existent allergic rhinitis, may lead to dehydration of the oral mucosa. As a result of mouth breathing, and the effects of anti-asthmatics and inhalation therapy, people with asthma are more likely to suffer from xerostomia (9), which may increase their susceptibility to dental caries (10). Because of the one or more of these plausible mechanisms, and perhaps due to any barriers in accessing oral healthcare, we hypothesize a connection between asthma and dental caries in adults living in the US.

Dental caries has been linked to numerous common chronic systemic diseases, such as diabetes (11–13), HIV infection (14), hepatitis, hypertension, stroke, liver disease (11). However, asthma, one of the most common chronic diseases and a major public health problem in adult populations (7), has not been adequately studied in relation to the outcome of dental caries, especially in the adult population in the US.

According to the published reviews of current literature regarding the association between asthma and caries, the vast majority of the published studies were conducted in pediatric populations (15–17). All dentate people, however, are susceptible to dental caries throughout their lifetime due to the collective effects of the accumulated risk factors over the course of aging (4).

Although asthmatic adults are also considered as patients with special needs (18), very few studies examined the association between asthma and dental caries specifically in adults (9,11,19–22). One such observational study reported that adult asthmatics had more untreated dental caries than non-asthmatics (20). Additional observational studies revealed that asthma was associated with higher dental caries experience (11,19). On the other hand, a number of studies failed to demonstrate a relationship between asthma and dental caries experience (9,21,22). None of those studies were conducted in a nationally representative sample in the United States. There is a dearth of large population-based studies which have examined the connection between asthma and dental caries in the US adults. Therefore, the purpose of this cross-sectional study was to investigate the association between asthma and dental caries in the US adult population using a nationally representative sample.

Methods

We used publicly available deidentified data from the continuous NHANES, 2009 to 2014 (23). In this study,

we included non-edentulous adults (≥ 18 -years old at the time of screening) with exam survey weights who received oral health-dentition assessment. Participants were excluded if their asthma-status was unknown or if they had incomplete dental examinations.

In essence, the continuous NHANES, conducted by the National Center for Health Statistics at the Centers for Disease Control and Prevention (CDC), is an ongoing, cross-sectional survey of noninstitutionalized civilian individuals selected to represent the US population of all ages. These data have been collected annually and publicly released in 2-year cycles since 1999. Individuals participating in this survey provided written informed consent. Detailed information about the NHANES is available on the CDC website (24).

Dental caries

Oral Health-Dentition examinations in the NHANES were performed by licensed, calibrated dental examiners in a mobile examination center. Dental-caries-experience was the primary outcome of interest, defined as ≥ 1 DFT (Decayed teeth + Filled teeth). Untreated dental caries, defined as ≥ 1 DT (Decayed teeth), was an additional outcome variable. Both of these outcomes were dichotomized as being either present or absent.

Furthermore, we computed DFT score as the sum of the number of carious (decayed) and restored (filled) teeth, and also DT score as the total number of carious (decayed) teeth in each study-participant's oral cavity. Then, we assessed the distributions of the DFT score and DT score in our study-sample, and accordingly categorized each of these outcomes into tertiles in increasing order of the number of affected teeth. Third molars were excluded from the assessment.

Asthma

"Asthma" was the key independent variable. Study-participants were categorized into current-asthmatics, former-asthmatics, and never-asthmatics based on their responses to following two questions related to asthma from the medical condition questionnaire in the NHANES:

1. Has a doctor or other health professional ever told you that you have asthma?
2. Do you still have asthma?

Individuals who responded "yes" to both of these questions were classified as current-asthmatics, and

those who had never been told that they had asthma were classified as never-asthmatics. Former-asthmatics, who reported being told that they had asthma but did not currently have it, were excluded because of the possible related biological complexities.

Covariates

Potential common covariates were selected from the continuous NHANES dataset and included age, race or ethnicity (Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, and Other Race/Multi Racial), gender, education, ratio of family income-to-poverty, cigarette smoking, body mass index (BMI), and diabetes. Additional population characteristics were obtained from the demographic data file to distinguish our study sample. Two categories of educational attainment ($<$ High School, and $\geq$ High School) and 2 categories of ratio of family income-to-poverty (<1 and ≥ 1) were formed. BMI was grouped into 3 categories: normal, overweight, and obese (25). Study-participants' diabetic status was categorized into non-diabetic, pre-diabetic, and diabetic based on their NHANES diabetes questionnaire data. Smoking status was classified as current, former, and never smokers. Nonsmokers included both, former and never smokers.

Statistical analysis

Descriptive statistical analyses were conducted to characterize our study-sample by dental-carries-experience, and to calculate the prevalence of asthma, dental-carries-experience and untreated dental caries. In bivariate analyses, the Rao–Scott chi-square test was used to examine the association between each independent variable of interest and the dichotomized outcome, dental-carries-experience.

Logistic regressions were performed to examine the relationship of asthma with each dichotomized outcome of interest, i.e. dental-carries-experience and untreated-dental-carries. The generalized logit model was applied to quantify the association of asthma with multilevel categories of dental-carries-experience and untreated dental caries. Crude and adjusted odds ratios and respective 95% confidence intervals were calculated to determine the degree of association. A model building approach was utilized to account for known confounding factors. Model 1 tested the crude association. Model 2 was adjusted for the age, race/ethnicity, gender, smoking, BMI, and diabetes. Model 3 was further adjusted for education in addition to

the covariates included in model 2. The final model 4 was fully adjusted for all of these covariates plus an additional variable of family income-to-poverty ratio.

Interactive effects of asthma and each covariate on dental-carries-experience and untreated-dental-carries were tested in the fully adjusted model. Each interaction was studied in a separate model in order to avoid multicollinearity. Effect measure modification of the association between exposure and the outcome was assessed based on the variable(s) which significantly interacted.

Using the NHANES sample-weights, our analyses were adjusted for national representation. Missing data were excluded. SAS software (SAS Institute, Carry, NC) version 9.4 was utilized to conduct all data management procedures and statistical analyses. Our study was determined “exempt” for the research purpose by the institutional review board of Albert Einstein College of Medicine.

Results

The characteristics of our study-population are presented in [Table 1](#). A total of 13,135 non-institutionalized civilian adults were included in this cross-sectional study who represented 175.26 million US adults. Average age of the study-participants was 46.5 years (Standard Error = 0.37). There was an almost equal distribution of males and females. In general, 67.2% experienced dental caries, and 8.6% of our study participants were current-asthmatics. As shown in [Table 1](#), there was a statistically significant association between asthma and dental-carries-experience. The prevalence of dental-carries-experience was more in current-asthmatic adults (73.2%) than never-asthmatic (66.6%) adults. Prevalence of untreated dental caries was 18.7% in our study-sample, affecting a higher proportion of current-asthmatics (25%) as compared to never asthmatics (18%).

Results of logistic regression analyses are presented in [Table 2](#). Overall, current-asthmatic adults had 37% higher odds of experiencing any dental caries as compared to never-asthmatic adults after adjusting for age, race or ethnicity, gender, smoking, BMI, diabetes, education and family income-to-poverty ratio. Similarly, current-asthmatics had higher odds of having any untreated dental caries than never-asthmatics in crude and adjusted models.

[Table 3](#) depicts the relationship between asthma and dental caries experience resulting from the generalized logit model application. Model 1 revealed the crude OR. In model 2, the association of asthma with

Table 1. Characteristics of study-sample, overall and by dental-carries-experience.^{a, b}

Characteristics	All N = 13,135 (100%)	No dental caries experience (DFT = 0) n = 4901 (32.8%)	Dental caries experience (DFT ≥ 1) n = 8234 (67.2%)	p-value ^c
Age (Years)				
18–29	2403 (17.6%)	746 (26.1%)	1657 (73.9%)	
30–44	3718 (29.5%)	1540 (39.0%)	2178 (61.0%)	
45–64	4531 (37.2%)	1702 (32.5%)	2829 (67.5%)	
≥65	2483 (15.7%)	913 (29.6%)	1570 (70.4%)	<0.0001
Gender				
Male	6472 (49.1%)	2537 (34.0%)	3935 (66.0%)	
Female	6663 (50.9%)	2364 (31.7%)	4299 (68.3%)	<0.0001
Race/Ethnicity				
Mexican American	1915 (8.8%)	891 (35.7%)	1024 (64.3%)	
Other Hispanic	1282 (5.8%)	517 (33.0%)	765 (67.0%)	
Non-Hispanic White	5386 (66.6%)	2039 (31.8%)	3347 (68.2%)	
Non-Hispanic Black	2864 (11.3%)	1028 (36.6%)	1836 (63.4%)	
Other Race/Multi Racial	1688 (7.5%)	426 (32.7%)	1262 (67.3%)	<0.0001
Nativity				
Foreign-Born	2739 (17.5%)	401 (14.3%)	1978 (85.7%)	
US Born	6570 (82.5%)	681 (8.3%)	5889 (91.7%)	<0.0001
Educational Attainment				
<High School	2777 (15.1%)	1231 (38.7%)	1546 (61.3%)	
≥High School	9540 (84.9%)	3243 (31.0%)	6297 (69.0%)	<0.0001
Ratio of family income to poverty				
<1	2706 (15.0%)	982 (31.4%)	1724 (68.6%)	
≥1	9318 (85.0%)	3476 (31.8%)	5842 (68.2%)	<0.0001
Marital status				
Never married	2208 (17.1%)	658 (27.7%)	1550 (72.3%)	
Married	6589 (57.8%)	2505 (33.7%)	4084 (66.3%)	
Others	3529 (25.2%)	1316 (31.8%)	2213 (68.2%)	<0.0001
BMI				
Normal	4042 (30.6%)	1410 (32.9%)	2632 (67.1%)	
Overweight	4224 (33.4%)	1630 (33.2%)	2594 (66.8%)	
Obese	4765 (36.0%)	1824 (32.3%)	2941 (67.7%)	0.08
Diabetic status				
Non-diabetic	10,841 (85.0%)	4084 (33.3%)	6757 (66.7%)	
Pre-diabetic	851 (6.4%)	288 (30.5%)	563 (69.5%)	
Diabetic	1437 (8.6%)	527 (30.3%)	910 (69.7%)	0.01
Smoking				
Current	2392 (18.0%)	884 (30.9%)	1508 (69.1%)	
Former	2853 (23.9%)	1054 (31.8%)	1799 (68.2%)	
Never	7375 (58.1%)	2632 (32.6%)	4743 (67.4%)	<0.0001
Asthma				
Current	1144 (8.6%)	374 (26.8%)	770 (73.2%)	
None	11,991 (91.4%)	4527 (33.4%)	7464 (66.6%)	0.0002

^aUnweighted N (Weighted %).^bColumn % in “All” column; row % in other columns.^cRao-Scott Chi-Square test of association between each independent variable and dental-carries-experience.**Table 2.** Associations of asthma with dental-carries-experience and untreated-dental-carries.

Model	Dental-carries-experience in ≥ 1 teeth OR (95% CI)	Untreated-dental-carries in ≥ 1 teeth OR (95% CI)
Model 1	1.43 (1.18–1.73)	1.57 (1.25–1.96)
Model 2	1.40 (1.15–1.70)	1.39 (1.11–1.74)
Model 3	1.40 (1.15–1.69)	1.42 (1.12–1.79)
Model 4	1.37 (1.13–1.66)	1.38 (1.10–1.73)

Model 1: Unadjusted.

Model 2: Adjusted by Age, Race, Gender, Smoking, BMI and Diabetes.

Model 3: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes and Education.

Model 4: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes, Education and Income/Poverty Ratio.

dental-carries-experience persisted, after adjusting for age, race, gender, smoking, BMI, and diabetes, as well as after additional adjusted analysis including education in model 3, and furthermore, income to poverty ratio in model 4. The fully adjusted ORs for dental caries experience in 1–5 teeth, 5–8 teeth and >8 teeth

as depicted in model 4 are 1.51 (95% CI: 1.16–1.95), 1.34 (95% CI: 1.10–1.62), and 1.29 (95% CI: 1.01–1.66), respectively.

The association between asthma and untreated dental caries, categorized based on the number of carious teeth (1, 2–3 and ≥4 teeth) are summarized in

Table 3. Association between asthma and dental-carries-experience, categorized by number of teeth.

Model	Dental caries experience in 1–5 teeth OR (95% CI)	Dental caries experience in 5–8 teeth OR (95% CI)	Dental caries experience in > 8 teeth OR (95% CI)
Model 1	1.50 (1.20–1.87)	1.47 (1.23–1.75)	1.23 (0.98–1.56)
Model 2	1.52 (1.19–1.95)	1.43 (1.18–1.74)	1.29 (1.01–1.65)
Model 3	1.53 (1.19–1.97)	1.42 (1.17–1.72)	1.29 (1.01–1.65)
Model 4	1.51 (1.16–1.95)	1.34 (1.10–1.62)	1.29 (1.01–1.66)

Model 1: Unadjusted.

Model 2: Adjusted by Age, Race, Gender, Smoking (3-levels), BMI Category (3-levels) and Diabetes (3-levels).

Model 3: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes, and Education.

Model 4: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes, Education and Income/Poverty Ratio.

Table 4. Association between asthma and untreated-dental-carries, categorized by number of teeth.

Model	1 carious tooth OR (95% CI)	2–3 carious teeth OR (95% CI)	≥4 carious teeth OR (95% CI)
Model 1	1.31 (0.99–1.74)	1.58 (1.10–2.26)	1.73 (1.16–2.59)
Model 2	1.21 (0.88–1.67)	1.50 (1.05–2.15)	1.52 (1.05–2.21)
Model 3	1.22 (0.88–1.69)	1.54 (1.07–2.22)	1.58 (1.08–2.32)
Model 4	1.23 (0.88–1.73)	1.45 (1.003–2.08)	1.52 (1.04–2.22)

Model 1: Unadjusted.

Model 2: Adjusted by Age, Race, Gender, Smoking, BMI and Diabetes.

Model 3: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes and Education.

Model 4: Adjusted by Age, Race, Gender, Smoking, BMI, Diabetes, Education and Income/Poverty Ratio.

Table 5. Association between asthma and dental caries experience (DFT) stratified by smoking status.

Asthma	Caries experience in 1–4 teeth OR (95% CI)	Caries experience in 5–8 teeth OR (95% CI)	Caries experience in > 8 teeth OR (95% CI)
Nonsmokers (never and former smokers)			
Model 1	1.83 (1.41–2.36)	1.63 (1.26–2.10)	1.45 (1.11–1.89)
Model 2	1.82 (1.36–2.42)	1.56 (1.20–2.03)	1.45 (1.11–1.89)
Model 3	1.84 (1.37–2.47)	1.55 (1.20–2.00)	1.45 (1.12–1.89)
Model 4	1.84 (1.35–2.51)	1.47 (1.12–1.93)	1.44 (1.09–1.90)
Current smokers			
Model 1	0.97 (0.62–1.51)	1.18 (0.73–1.89)	0.90 (0.57–1.43)
Model 2	0.91 (0.58–1.44)	1.15 (0.73–1.82)	0.86 (0.54–1.38)
Model 3	0.93 (0.58–1.49)	1.14 (0.71–1.84)	0.87 (0.54–1.39)
Model 4	0.87 (0.55–1.37)	1.05 (0.65–1.70)	0.90 (0.65–1.45)

Model 1: Unadjusted.

Model 2: Adjusted by Age, Race, Gender, BMI, and Diabetes.

Model 3: Adjusted by Age, Race, Gender, BMI, Diabetes, and Education.

Model 4: Adjusted by Age, Race, Gender, BMI, Diabetes, Education, and Family income-to- poverty ratio.

Table 4. Current-asthmatics had higher odds of having untreated dental caries in reference to never-asthmatics in all 3 categories of the number of carious teeth. These odds were increasing with an increasing order of the number of untreated carious teeth. We observed consistency in these results throughout from unadjusted Model 1 to fully-adjusted Model 4.

While examining the interactive effect of other covariates with asthma, a significant interaction was noticed between smoking and asthma for dental-carries-experience (p values < 0.001) and untreated-dental-carries (p values < 0.001). Stratification by smoking status for both the outcomes, dental-carries-experience and untreated-dental-carries, are presented in **Tables 5** and **6**, respectively. It is worth noting that asthma was associated with all three categories of dental caries experience among nonsmokers only. On the other hand, although current-asthmatics had higher

odds of having a greater number of untreated carious teeth regardless of the smoking status, the associations in all three categories were stronger and statistically significant in the subpopulation of current-smokers. As shown in fully adjusted model 4, relative to never-asthmatics, asthma doubled the odds for untreated dental caries in current smokers after controlling for common demographic factors, socioeconomic status, diabetes, and BMI.

Discussion

This cross-sectional study using the NHANES data, aimed to investigate the relationship between asthma and dental-carries-experience in a nationally representative sample of US adult population. It also sought to separately examine the relationship between asthma and untreated dental caries in this population.

Table 6. Association between asthma and untreated dental caries (DT) stratified by smoking status.

Asthma	1 carious tooth OR (95% CI)	2–3 carious teeth OR (95% CI)	≥4 carious teeth OR (95% CI)
Nonsmokers (never and former smokers)			
Model 1	1.05 (0.76–1.45)	1.26 (0.78–2.04)	1.33 (0.83–2.12)
Model 2	1.02 (0.71–1.46)	1.20 (0.74–1.95)	1.30 (0.82–2.06)
Model 3	1.01 (0.69–1.48)	1.23 (0.75–2.03)	1.39 (0.87–2.23)
Model 4	1.04 (0.70–1.54)	1.14 (0.68–1.89)	1.33 (0.83–2.12)
Current smokers			
Model 1	2.09 (1.25–3.51)	2.31 (1.26–4.23)	2.23 (1.34–3.71)
Model 2	1.90 (1.09–3.30)	2.39 (1.34–4.26)	2.10 (1.29–3.42)
Model 3	1.90 (1.09–3.32)	2.46 (1.37–4.40)	2.11 (1.28–3.48)
Model 4	1.87 (1.05–3.33)	2.31 (1.27–4.21)	2.06 (1.25–3.40)

Model 1: Unadjusted.

Model 2: Adjusted by Age, Race, Gender, BMI, and Diabetes.

Model 3: Adjusted by Age, Race, Gender, BMI, Diabetes, and Education.

Model 4: Adjusted by Age, Race, Gender, BMI, Diabetes, Education, and Family income-to- poverty ratio.

Findings from this study revealed that asthma was associated with both, dental-carries-experience, and untreated-dental-carries. Current-asthmatic adults were more likely to experience dental caries and they were more likely to have greater number of untreated carious teeth as compared to never-asthmatic adults in the US after controlling for common confounders including demographic factors, socioeconomic status, smoking, and comorbid conditions such as diabetes and obesity. These findings are consistent with those few previously conducted studies in adult populations evaluating an association between asthma and dental caries (11,19,20,26).

In our study, the asthma-carries association among current-smokers was different than what we observed among nonsmokers. Among the nonsmokers, current-asthmatics were more likely to experience dental caries (combined decayed and filled teeth) than their never asthmatic counterpart. We observed inconsistencies and lack of association between asthma and dental-carries-experience in current-smokers. However, in the subpopulation of current-smokers, current-asthmatic adults were more than twice as likely to have ≥4 untreated carious teeth as compared to their never-asthmatic reference group. Such heterogeneity of the association by smoking for both the outcomes, dental caries experience and untreated dental caries, might be attributable to the higher prevalence of untreated dental caries, greater number of untreated decayed teeth, lower prevalence of restored (filled) teeth, and/or a smaller number of filled teeth in current asthmatic adults amongst the smokers than nonsmokers.

This stratification based on the smoking status highlights the impact of smoking on the magnitude of the association between asthma and untreated-dental-carries. According to these findings in our study, it might be interpreted that in the US, the burden of untreated dental caries is significantly more in current-asthmatic adults than non-asthmatics, especially

in the sub-population of current-smokers. These findings support the importance of oral health promotion in this population and the need to increase awareness for dental care among current-asthmatic adults who currently smoke. The association of smoking with higher number of untreated carious teeth, therefore, identifies a role for discussion of smoking cessation.

It is worth mentioning that unlike many other studies, the present study examined the association of asthma with two separate dichotomized as well as categorized outcomes, dental caries experience and untreated dental caries. The majority of the previously published studies used the decayed, missing, and filled teeth (DMFT) or decayed, missing, and filled surfaces (DMFS) index as an indicator of dental caries (8,11,19). However, in this study, we utilized Decayed Filled Teeth index to measure dental-carries-experience, and number of only decayed teeth to measure untreated-dental-carries separately. Nonetheless, missing teeth were not included in the measurement of any of these outcomes in this study, as teeth could be missing because of many other reasons in addition to dental caries. We believed that inclusion of missing teeth might have overestimated the outcome of dental-carries-experience, and is an area of investigation that calls for separate research.

Dental caries is a multi-factorial, multi microbial infectious disease in which there is demineralization of inorganic substance and destruction of the organic matrix of the teeth. The exact mechanism by which asthma is associated with dental caries still remains unclear. Since asthma involves systemic and airway immune system (27), these alterations may influence immune responses to oral microflora. As a result, dysbiotic microbial communities may flourish in the oral cavity and might contribute to the susceptibility to dental caries in asthmatic patients. Since inhaled steroids are the first line of preventive asthma medications, they may additionally contribute to the risk of

dental caries development (8). Other possible mechanisms which have been hypothesized for an association between asthma and dental caries include lower plaque pH, decreased salivary flow and xerostomia.

The considerably higher number of untreated carious lesions in asthmatic adults in the US suggests potentially higher total healthcare cost and inevitably a substantial amount of financial burden to society. Although there are several risk factors associated with dental caries, exposure to many of these factors could be minimized or prevented by creating the awareness for oral health and providing timely and adequate access to oral healthcare. Therefore, community-based disease prevention and health promotion programs targeted to current-asthmatic adults should include a focus on providing oral hygiene instructions, oral prophylaxis, topical fluoride varnish application, and pit and fissure sealants.

Published studies evaluating the association between asthma and dental caries, especially exclusively in the adult population, are relatively few and present large variations in terms of the study design, sample size, and dental caries assessment (11,19–22,26). The difficulty that is involved in recruiting a sizeable homogenous group to investigate this association may potentially explain the relative lack of these studies, which sometimes limits the possibility of drawing reliable conclusions. In our study, we addressed this knowledge gap by utilizing one of the largest national datasets – NHANES, and focusing exclusively on adults (≥ 18 years old) living in the US.

Important strengths of our study are the objective clinical dental examination data, systematically collected by the calibrated licensed dental examiners, and a large nationally representative study-sample. To the best of our knowledge, this is the first large population-based study in the United States, conducted in a nationally representative sample, evaluating the association between asthma and two separate outcomes, dental-carries-experience and untreated-dental-carries, exclusively in the adult population.

Nonetheless, this study has a number of limitations which need to be noted. Given the cross-sectional nature of data collection, we could not include the duration, control, and severity of asthma in this study as those data were not readily available directly from the NHANES data files. Furthermore, our study was limited by the absence of information on asthma treatment - one of the plausible mechanisms underlying higher caries experience in asthmatic adult population (8,10). Many potential explanatory variables, such as genetics, nutrition, fluoride, medications,

access to oral healthcare were not included because that information was either not available or limited to data collected in specific years only. Therefore, the regression analyses in this study were limited to only those important variables, namely, common demographic factors, BMI, diabetes, smoking, and socioeconomic status, which were consistently available directly from all three NHANES datasets: 2009–2010, 2011–2012, and 2013–2014. Furthermore, diet and oral hygiene status were not considered, and hence confounding by these variables might be present in the regression models. Although physician-diagnosis of asthma was directly reported by the study-participants, it is considered to have a high level of validity and reliability (28,29).

Since it was a cross-sectional study design, both, exposure and outcome were determined simultaneously for each study-participant. This type of study design suffers from low internal validity, and does not provide details on the temporal relationship between exposure and outcome. Therefore, no claim can be made regarding causation. Prospective research with a more robust design, and longitudinal and reliable clinical and laboratory data is warranted to further confirm the findings of this study.

This observational study suggests another link between systemic and oral diseases in adults and demonstrates a need for continued interprofessional collaboration to address population health. Our study opens the new direction to conduct future research to evaluate the effects of duration, control, and severity of asthma on dentition in adult populations. More well-controlled longitudinal studies are required to further evaluate factors determining dental health in asthmatic adults, and to clarify the potential role of asthma in the occurrence of dental caries.

Conclusion

Current-asthmatic adults are more likely to experience dental caries, and they are more likely to have a greater number of untreated carious teeth as compared to never-asthmatic adults. Special attention is therefore required to maintain and promote oral health in this population currently suffering from asthma. The study provides useful information to recommend for interprofessional collaboration with an ultimate goal of establishing caries control and health promotion. It is particularly important in the subgroup of current-smokers to increase awareness of needed dental care in order to reduce the burden of untreated dental caries.

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Declaration of interest

The authors declare that they have no relevant conflicts of interest.

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