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Asthma, COPD, Tooth Loss, and Edentulism among Adults in the United States: 2016 Behavioral Risk Factor Surveillance Survey

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Abstract

Background.—Adults with chronic respiratory conditions, specifically asthma and/or chronic obstructive pulmonary disease (COPD) may be at risk for poor oral health due to systemic inflammation, challenges in routine dental care, and side effects of medications used to treat these conditions. We examined the association of asthma, COPD, and co-existing asthma and COPD (asthma-COPD overlap syndrome, or ACOS) with tooth loss among US adults.

Methods.—Cross-sectional design was employed using 2016 Behavioral Risk Factor Surveillance System data (N=387,217). Number of missing permanent teeth was categorized into 4 groups: 1)asthma only (N = 38,817); 2)COPD only (N = 19,819); 3)ACOS (N=13,494); and 4)no asthma, no COPD (N =315,087). Adjusted multinomial logistic regressions examined association between asthma/COPD categories and tooth loss.

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All authors contributed to the conceptualization, design, analysis, and discussion of this manuscripts. Dr. Dwibedi did lead the process, thus her placement as the first author. The team worked collaboratively and all participating the in actual writing, revising, and final preparations.

Conflicts of Interest

The authors report no conflicts of interest.

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Results.—5.3% of adults reported they were edentulous; 10.7% reported ≥ 6 , not all teeth missing. Adults with asthma only, COPD only, and with ACOS had higher odds of reporting tooth loss (missing ≥ 6 teeth, all) compared to no asthma, no COPD group; AORs were 1.12(95% CI=1.00–1.26) to 2.04(95% CI=1.85–2.26). A lower percentage of adults with COPD, and ACOS visited dentists in the past year. Interactive associations suggested adults with asthma and/or COPD with dental visits were less likely to report edentulism compared to those with neither asthma nor COPD and no dental visits.

Conclusions.—Adults with asthma and/or COPD had higher odds of tooth loss compared to those with neither asthma nor COPD.

Practical Implications.—Adults with asthma and/or COPD should maintain routine dental visits to reduce risk of tooth loss.

Introduction

Adults with chronic respiratory conditions, specifically individuals with asthma and/or chronic obstructive pulmonary disease (COPD), may be at risk for poor oral health due to systemic inflammation, challenges in routine dental care, and side effects of medications, particularly those with corticosteroids.^{1–3} Asthma and/or COPD medications can cause dry mouth symptoms which may lead to oral candidiasis and dental erosions.⁴ Adults with asthma and/or COPD are more likely to have caries and periodontal disease,^{4, 5} the primary risk factors for tooth loss in adulthood.^{6, 7} For example, in a study of adults (n=200; 100 with asthma and 100 controls), people with asthma were more likely to have more untreated dental caries (PR = 1.23; 95% CI 1.23–1.58; p < 0.001) than the participants who did not have asthma.⁸ Similarly, in two case-control studies conducted in Brazil (n=220 and n=260)^{9, 10} severe asthma was associated with periodontal disease. Not all of the research on asthma and periodontal disease was consistent. Researchers examining individuals with a high BMI found that participants with severe periodontal disease were less likely to have asthma.¹¹ A systematic review and meta-analysis of 21 studies concerning asthma and periodontal disease concluded that there is a strong suggestive association, however, there was a need for more research.¹²

It is important to study tooth loss among asthma and/or COPD patients because tooth loss of even one tooth can lead to adverse disease-specific outcomes¹⁰ (e.g., compromised oral hygiene resulting in dental caries in the remaining teeth/surfaces made more vulnerable following the loss of a tooth) or it can further accelerate negative disease-specific outcomes,^{13–15} and health-related quality of life.^{16, 17} Researchers conducting a study in Korea reported a direct association between age at asthma diagnosis and tooth loss. They found in their study of 65,973 subjects a significant increase in tooth loss due to caries after early asthma diagnosis at 0–6 years ($\beta = 0.560$, p < .001) and 7–12 years ($\beta = 0.437$, p < .001).¹⁸ Another study also conducted in Korea reported that “severe periodontitis was closely associated with COPD after adjusting for confounding factors.”¹⁹

There is indirect evidence of negative consequences of tooth loss and edentulism and/or disease-specific outcomes as reported in studies conducted in countries such as China, Germany and Korea. Researchers who used data from the Korean National Health and

Nutrition Examination Survey, 2010–2012 found that the number of permanent teeth in participants with COPD was significantly lower than controls with normal lung function, suggesting that missing permanent teeth are associated with poor overall health outcomes.¹⁹ Similar results were observed in participants from Germany, in which researchers reported that edentulism was associated with lower respiratory capacity among adults with COPD.²⁰ Researchers conducting a cohort study of edentulous patients with COPD in the US reported the edentulous participants had a higher incidence and were more likely to have COPD-related hospitalizations than dentate patients with COPD.²¹

Whereas we have noted some limited research conducted in China, Germany, and Korea, to date, there are few studies in the US in which the combined asthma and COPD relationship with tooth loss has been examined. It is important to analyze these two conditions in combination as asthma and COPD often co-exist.^{22, 23} The co-morbidities are sometimes referred to as asthma-COPD overlap syndrome (ACOS).²⁴ Our preliminary estimate from the Behavioral Risk Factor Surveillance System (BRFSS) data suggest that there are at least 5.3 million adults, who have ACOS. Although asthma and COPD are different in terms of diagnostic and management approaches, the oral health risks of asthma and COPD are similar because 1–3 Asthma and/or COPD medications can cause dry mouth symptoms which may lead to oral candidiasis and dental erosions.⁴ It is plausible that individuals with asthma and/or COPD may be at higher risk for tooth loss compared to those without asthma and/or COPD because of the increased disease severity in terms of airflow obstruction²⁵ and compromised lung function negatively affecting multiple dimensions of oral health.²⁰ Therefore, the purpose of this research is to determine the association of asthma and/or COPD and tooth loss among US adults using a nation-wide database, the BRFSS. We anticipate that adults with ACOS may be more likely to experience tooth loss including edentulism compared to those without asthma and without COPD.

Methods

Study Design

We used a retrospective, observational and cross-sectional design.

Data Source

The data in this study were from 2016 BRFSS data. The BRFSS researchers collected information on US residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services. They conduct more than 400,000 adult interviews each year via telephone. The BRFSS is the largest continuously conducted health survey system in the world. (<https://www.cdc.gov/brfss/index.html>).

Study Sample

The final study sample consisted of 387,217 adults (age ≥ 18 years). We excluded 20% (N = 99, 086) of the sample for the following reasons: living in Guam or Puerto Rico, interviews conducted and completed in 2016, and missing data on asthma/COPD status, tooth loss, age, and sex. Individuals living in Guam and other territories were excluded because of key

differences in how healthcare is covered by different health insurance plans. Details of our sampling exclusion method is illustrated in appendix 1.

Dependent Variable: Self-reported missing permanent teeth categories.—The BRFSS interviewers asked interviewees the following question and restrictive sentences: “How many of your permanent teeth have been removed because of tooth decay or gum disease? Include teeth lost to infection, but do not include teeth lost for other reasons, such as injury or orthodontics. (If wisdom teeth are removed because of tooth decay or gum disease, they should be included in the count for lost teeth).” The possible answers to the question were: 1) “1 to 5”; 2) “6 or more but not all”; 3) “all”; and 4) “none.”

Key Independent Variable: Self-reported Asthma and/or COPD Status.—We identified whether an interviewee ever had asthma and/or COPD based on two BRFSS survey questions as to if the interviewee had ever been told he or she had asthma and/or COPD. We categorized respondents into four groups: 1) asthma only; 2) COPD only; 3) ACOS; and 4) no asthma and no COPD.

Other Explanatory Variables—We used the Andersen’s healthcare utilization model^{26, 27} and included the following explanatory variables: 1) predisposing factors: sex (female/male), race/ethnicity (Non-Hispanic white/Non-Hispanic black/Hispanic/other/missing), age in years (18–34/35–44/45–54/55–64/65–74/75/above); 2) enabling factors: marital status (married/widowed/divorced-separated/never married/missing), highest education level (less than high school/high school graduate/some college-technical school/college-technical school degree/above/missing), employment status (employed/not employed/retired/other/missing), health insurance coverage (yes/no/missing); 3) need: self-perceived physical health (excellent/very good/good/fair/poor/missing); 4) personal health practices: dental visit in the past year (yes/no/missing), body mass index (underweight/normal/overweight/obese/morbid obese), smoking status (current smoker/former smoker/never smoker/missing), alcohol drinking (non-drinker/moderate/heavy/missing), and physical activity (yes/no/missing); and 5) the external environment: region (Northeast/Midwest/South/West/missing).

We included self-rated health (excellent, very good, good, fair, poor) as one of the independent variables as a proxy for comorbidity. We included self-rated health for ease of interpretation. Existing studies have documented that self-rated health status is highly correlated with multimorbidity/comorbidity^{28–32}.

Statistical Analyses

Chi-square tests were used to examine the unadjusted subgroup differences by asthma and/or COPD status and the number of missing teeth. For adjusted analyses, we employed multivariable multinomial logistic regressions to study the association between permanent teeth loss and asthma and/or COPD status. In this regression we controlled for sex, age, race/ethnicity, marital status, education, income, health insurance, physical health, alcohol use, tobacco use, obesity, physical activity, region, and any dental visit in the past year. In this multivariable multinomial logistic regression, above mentioned variables were entered in

blocks. We also tested the interaction between asthma and/or COPD status and dental visits in the past year on tooth loss. Data were analyzed with SAS 9.4® (Cary, NC) software considering the sample weights, provided in the BRFSS 2016 data set. This study received acknowledgement as a Non-Human Subjects Research by the West Virginia University Institutional Review Board (Protocol number: 1712881464). The research was followed strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Results

There were 387,217 participants in the study. A majority of adults were female (52%) and white (65%). Among adults in the US, 10.9% had asthma, 4.0% had COPD, 2.8% had ACOS, and 82.3% had no asthma and no COPD (Table 1). A lower percentage of adults with COPD (49.4%) or ACOS (49.8%) had a dental visit in the past year compared to participants without asthma and without COPD (66.7%). Tobacco use and physical inactivity were higher in adults with COPD and ACOS as compared to those with no asthma and no COPD.

Presented in Table 2 are the associations of selected variables by the number of missing permanent teeth (none; 1–5; greater than 6 missing teeth but not all; and all). There were 54.4% adults without any tooth loss. This percentage was lower among participants with COPD alone (24.3%) and for ACOS (26.2%). Overall, 10.7% of adults reported having 6 or more missing teeth but not all; this percentage was higher among participants with COPD (26.6%) and ACOS (27.5%). Overall, 5.3% were missing all permanent teeth. This percentage is higher among participants with COPD (20.4%) and ACOS (17.9%).

Among participants who had a dental visit in the past year, only 2.1% had all permanent teeth missing. This percentage was higher in adults without a dental visit in the past year (11.2%).

Adjusted Analyses of Number of Missing Teeth Categories by Asthma and/or COPD Status

Multinomial logistic regression models were conducted to compare missing teeth categories by asthma/COPD status (Table 3). For all of the models the reference group was no permanent teeth removed. In the unadjusted analysis, compared to participants without asthma and without COPD, participants with COPD alone had an odds ratio of 10.97 (95% Confidence Interval (CI), 10.03, 11.99) for having all teeth removed. The odds ratios for COPD alone remained higher than the other categories of diagnoses in nearly all of the adjusted models. When other explanatory variables--sex, age, race/ethnicity, marital status, education, income, health insurance, physical health, alcohol use, tobacco use, obesity, physical activity, region, and any dental visit in the past year--were in the model, the odds ratio of COPD alone for all permanent teeth missing was significant, but attenuated (2.04 [95% CI, 1.85–2.26]).

In contrast, the association between asthma alone and tooth loss was less consistent throughout various models (Table 3). The odds ratio under the unadjusted model were less than 1 (from .85 to .95 for the different tooth loss categories), and reversed to above 1 (from

1.01 to 1.13 for the different tooth loss categories) when controlling for all the explanatory variables. The magnitudes were low with odds ratios just over 1, and the p-values were also larger compared to COPD alone.

We also found that adults with dental visits during the past year had lower odds of missing permanent teeth categories (6 or more but not all; and all permanent teeth missing) compared to those without a dental visit in the past year (AOR = 0.87, 95% CI = 0.83, 0.92; AOR = 0.24, 95% CI = 0.22, 0.26).

Interaction between Asthma/COPD Categories and Dental Visits on the Number of Missing Permanent Teeth Categories

In our study lower percentage of patients with asthma and COPD visited dentist in the past year. Among adults with COPD or ACOS, only 50% had a dental visit in the past year. This percentage was higher among adults with asthma only (65.8%) or those without asthma and without COPD (66.7%). Dental visits may be burdensome on these patients due to their condition-related sequelae such as shortness of breath at rest, productive cough, upper respiratory tract infection, or an oxygen saturation level less than 91% make routine dental treatment difficult.^{3, 33–36} Therefore, we explored whether those with asthma/COPD may have greater benefits with dental visits compared to those without asthma and without COPD based on the the interactive association between asthma and/or COPD categories and dentist visits on tooth loss. The interactive associations were based on the following categories: 1) asthma only with dental visits; 2) COPD only with dental visits; 3) ACOS with dental visits; 4) no asthma and no COPD with dental visits; 5) asthma only without dental visits; 6) COPD only without dental visits; 7) ACOS without dental visits and 8) No asthma and no COPD without dental visits. We also created a missing indicator variable for dental visits. In this regression, the group “no asthma and no COPD without dental visits” was used as the reference group.

The interaction terms suggested that among all categories of asthma and COPD, participants with dental visits within the previous year were less likely to have all permanent teeth missing. For example, compared to adults with no asthma, no COPD and no dental visit in the past year, participants with COPD and dental visits in the past year (AOR = 0.53; 95% CI = 0.45, 0.63) and those with ACOS and dental visits ((AOR = 0.45; 95% CI = 0.37, 0.54) were less likely to have all teeth missing.

Discussion

The researchers of this study examined the association of asthma and/or COPD (asthma-COPD overlap syndrome) and tooth loss among adults using a nation-wide database, the BRFSS. Similarly, individuals with ACOS also were significantly more likely to have higher odds of missing permanent teeth (all categories) compared to those without asthma or COPD. It is worth noting that an association between COPD and tooth loss had been reported in one study using BRFSS, 2012 data.²⁵ The researchers reported that smoking and tooth loss were associated with an increased likelihood of COPD.³⁷ Similarly, alveolar bone loss and COPD were found to be associated in a longitudinal study of 1,118 U.S. Veterans.³⁸ National Health and Nutrition Examination Survey I (NHANES) data (n=23,808) were

analyzed to determine if there were an association of confirmed chronic respiratory disease (n=41) and periodontal index and no statistically significant association was determined;³⁹ however, using NHANES III data, an association of periodontal disease and COPD was determined.² While our data are based on self-reported information, published studies support the use of self-report data for COPD,⁴⁰ asthma,⁴¹ and tooth loss.⁴² Although we observed that adults with asthma had lower unadjusted odds of missing 1–6 permanent teeth or all teeth, this association reversed once age, sex, and race were entered into the model. Such reversal with odd ratio values near one may indicate sample variation occurring with the sample of participants who have asthma.

Clinical Significance

Overall, participants who had who had dental visits in the past year were associated with were less likely to suffer complete tooth loss as compared to participants who did not have dental visits in the past year. When we explored the interactive associations of asthma/COPD categories to tooth loss, we found that among all categories of asthma and COPD, participants with dental visits within the previous year were less likely to have all permanent teeth missing. Taken together, the interaction findings suggest that dental care within the previous year is particularly important for adults with respiratory conditions, specifically COPD combinations. The adjusted odds ratio of all missing teeth for asthma only was statistically significant and very small. This association may not be clinically significant and may have been due to a very large sample size. However, the association of asthma only + dental visit to all missing teeth was highly significant with adjusted odds ratio of 0.27 and 95% CI = 0.23 and 0.33 suggesting that dental visits have a very strong negative association to all missing teeth.

Other researchers have indicated that patients with asthma and COPD can improve their oral health (reduce caries, periodontal disease, and mucositis) with routine visits for dental care.⁴³ However, patients with asthma and/or COPD may not seek routine dental care due to their condition-related sequelae such as shortness of breath at rest, productive cough, upper respiratory tract infection, or an oxygen saturation level less than 91% which may make routine dental treatment difficult.^{3, 33, 35, 36, 44} Many dental procedures are especially stressful on patients with chronic respiratory diseases.³ Published literature suggests that individual conditions such as diabetes, heart disease, kidney disease, and Alzheimer's disease may be associated with periodontal disease^{45–51}. Collectively, findings from published studies and the current study highlight the need for oral health surveillance of all patients with particular attention to specific co-occurring chronic conditions to prevent tooth loss and its associated negative health outcomes.

Limitations and Strengths—A limitation of this study was that survey respondents were individuals with either cell phones or landline telephones. BRFSS researchers did not contact individuals who had neither. Therefore, study results may not be generalizable to the US population. A second limitation is that all data are self-reported. As such, self-report of asthma and/or COPD, tooth loss, visits to the dentist, and the other variables of interest are subject to social desirability bias in which the respondent may want to appear to follow the norms of the interviewer/society and may respond in such a manner as to reflect those

norms. Such bias would misclassify respondents. The nature of a cross-sectional study is limited to describing associations, rather than indicating causation. Thus, the relationship can be the result of COPD/asthma leading to tooth loss, or poor oral health (resulting in tooth loss) influencing the progression of lung disease. Medication use may have an impact on tooth loss, in the absence of adjustment for medication use, our study findings may overestimate the association of asthma/COPD status to tooth loss.

Nevertheless, this study has several strengths. We used population-based data from a well-established survey, the BRFSS, which is the largest telephone survey in the world of adults over 18 years of age. By including both cell phone and landline, the survey can be considered as a more representative sample of adults. It is the first study to report the association between ACOS and tooth loss in the US. We also controlled for a comprehensive list of factors associated with tooth loss. BRFSS includes data on actual behaviors, rather than on attitudes or knowledge; thus findings from our study can be useful for planning and developing health promotion and disease prevention programs.

Future research

Several areas require further research to explain differences in tooth loss among individuals with asthma, COPD, ACOS, and neither asthma nor COPD. There may be significant deleterious effects relating to specific COPD medications; differences in diet; work selected; and other life-style choices. Periodontal treatment may provide opportunities to reduce the risk of periodontal disease among adults with asthma, COPD, and ACOS. Researchers conducting a propensity-matched study using Taiwan National Health Insurance data (n=9,542) determined that periodontal treatment in people with asthma was associated with decreased risk of hospitalization for adverse respiratory events and mortality compared to people with asthma without periodontal disease.⁵² Future research is needed to conclusively state this relationship.

Implication

Individuals with asthma and/or COPD have poorer oral health - as measured by number of missing permanent teeth - compared to those without asthma and without COPD.

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Appendix 1

Study Sample:

Behavioral Risk Factor Surveillance System, 2016

References

1. Shashikiran N, Reddy V, Raju PK. Effect of antiasthmatic medication on dental disease: dental caries and periodontal disease. *Journal of Indian Society of Pedodontics and Preventive Dentistry* 2007;25(2):65–68. [PubMed: 17660639]
2. Scannapieco FA, Ho AW. Potential associations between chronic respiratory disease and periodontal disease: analysis of National Health and Nutrition Examination Survey III. *Journal of Periodontology* 2001;72(1):50–56. [PubMed: 11210073]

3. Rahman S, Faruque M, Khan M, Hossain S. Dental management of COPD patient. *Bangladesh Medical Journal Khulna* 2012;44(1-2):21–24.
4. Godara N, Godara R, Khullar M. Impact of inhalation therapy on oral health. *Lung India : Official Organ of Indian Chest Society* 2011;28(4):272–75. [PubMed: 22084541]
5. Xie Q, Ainamo A. Association of edentulousness with systemic factors in elderly people living at home. *Community Dentistry and oral Epidemiology* 1999;27(3):202–09. [PubMed: 10385358]
6. Dye BA, Thornton-Evans G, Li X, Iafolla T. Dental caries and tooth loss in adults in the United States, 2011–2012: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics; 2015.
7. Felton DA. Complete edentulism and comorbid diseases: an update. *Journal of Prosthodontic* 2016;25(1):5–20.
8. Chala S, Rouiffi S, Soualhi M, et al. Association between untreated carious lesions and asthma in adults at Rabat University Hospital, Morocco: a cross sectional study. *BMC Research Notes* 2017;10(1):221. [PubMed: 28651623]
9. Gomes-Filho IS, Soledade-Marques KR, Seixas da Cruz S, et al. Does periodontal infection have an effect on severe asthma in adults? *Journal of Periodontology* 2014;85(6):e179–e87. [PubMed: 24224961]
10. Soledade-Marques KR, Gomes-Filho IS, da Cruz SS, et al. Association between periodontitis and severe asthma in adults: A case–control study. *Oral diseases* 2018;24(3):442–48. [PubMed: 28833877]
11. Rivera R, Andriankaja OM, Perez CM, Joshipura K. Relationship between periodontal disease and asthma among overweight/obese adults. *Journal of clinical periodontology* 2016;43(7):566–71. [PubMed: 27028763]
12. Moraschini V, Calasans-Maia JdA, Calasans-Maia MD Association between asthma and periodontal disease: A systematic review and meta-analysis. *Journal of Periodontology* 2018;89(4):440–55. [PubMed: 28871892]
13. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bulletin of the World Health Organization* 2005;83(9):661–69. [PubMed: 16211157]
14. Liu Z, Zhang W, Zhang J, et al. Oral hygiene, periodontal health and chronic obstructive pulmonary disease exacerbations. *Journal of Clinical Periodontology* 2012;39(1):45–52. [PubMed: 22092913]
15. Haworth S, Shungin D, Kwak SY, et al. Tooth loss is a complex measure of oral disease: Determinants and methodological considerations. *Community Dentistry and Oral Epidemiology* 2018.
16. Kandelman D, Petersen PE, Ueda H. Oral health, general health, and quality of life in older people. *Special Care in Dentistry* 2008;28(6):224–36. [PubMed: 19068063]
17. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global Oral Health Programme. *Community Denistry and Oral Epidemiology* 2005;33(2):81–92.
18. Choi H, Bae K-H, Lee J-WJAOS Association between age at asthma diagnosis and tooth loss. *Acta Odontologica Scandinavica* 2018;76(7):466–72. [PubMed: 29409361]
19. Chung JH, Hwang HJ, Kim SH, Kim TH. Associations between periodontitis and chronic obstructive pulmonary disease: the 2010 to 2012 Korean National Health and Nutrition Examination Survey. *Journal of Periodontology* 2016;87(8):864–71. [PubMed: 26912338]
20. Henke C, Budweiser S, Jörres RA. Lung function and associations with multiple dimensions of dental health: a prospective observational cross-sectional study. *BMC Research Notes* 2016;9(1):274. [PubMed: 27184138]
21. Barros SP, Suruki R, Loewy ZG, Beck JD, Offenbacher S. A cohort study of the impact of tooth loss and periodontal disease on respiratory events among COPD subjects: modulatory role of systemic biomarkers of inflammation. *PLoS One* 2013;8(8):e68592.
22. Shaya FT, Dongyi D, Akazawa MO, et al. Burden of concomitant asthma and COPD in a Medicaid population. *J Chest* 2008;134(1):14–19.
23. Guerra S Asthma and chronic obstructive pulmonary disease: natural history, phenotypes, and biomarkers. *J Current Opinion in Allergy and Clinical Immunology* 2009;9(5):409–16.

24. Gibson PG, Simpson J. The overlap syndrome of asthma and COPD: what are its features and how important is it? *J Thorax* 2009;64(8):728–35.
25. Soriano JB, Davis KJ, Coleman B, et al. The proportional Venn diagram of obstructive lung disease: two approximations from the United States and the United Kingdom. *J Chest* 2003;124(2):474–81.
26. Andersen R A behavioral model of families' use of health services. Chicago: Center for Health Administration Studies; 1968.
27. Andersen RM. Revisiting the behavioral model and access to medical care: does it matter? *Journal of Health and Social Behavior* 1995:1–10.
28. Plesh O, Adams SH, Gansky SA. Self-reported comorbid pains in severe headaches or migraines in a US national sample. *Headache: The Journal of Head and Face Pain* 2012;52(6):946–56.
29. Perruccio AV, Katz JN, Losina E. Health burden in chronic disease: multimorbidity is associated with self-rated health more than medical comorbidity alone. *Journal of clinical epidemiology* 2012;65(1):100–06. [PubMed: 21835591]
30. Wilcox VL, Kasl SV, Idler EL. Self-rated health and physical disability in elderly survivors of a major medical event. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 1996;51(2):S96–S104.
31. Bosworth HB, Siegler IC, Brummett BH, et al. The relationship between self-rated health and health status among coronary artery patients. *Journal of Aging and Health* 1999;11(4):565–84. [PubMed: 10848078]
32. Hoeymans N, Feskens EJ, Kromhout D, Van den Bos GA. The contribution of chronic conditions and disabilities to poor self-rated health in elderly men. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences* 1999;54(10):M501–M06.
33. Gibson E Dental management of the medically compromised patient: Nature Publishing Group; 2007.
34. Claramunt Lozano A, Sarrión Pérez MG, Gavalda Esteve C. Dental considerations in patients with respiratory problems. 2011.
35. Steinbacher DM, Glick M. The dental patient with asthma: an update and oral health considerations. *The Journal of the American Dental Association* 2001;132(9):1229–39. [PubMed: 11665347]
36. Waldman HB, Fenton SJ, Perlman SP, Cinotti DA. Preparing dental graduates to provide care to individuals with special needs. *Journal of Dental Education* 2005;69(2):249–54. [PubMed: 15689609]
37. Cunningham TJ, Eke PI, Ford ES, et al. Cigarette smoking, tooth loss, and chronic obstructive pulmonary disease: findings from the behavioral risk factor surveillance system. *Journal of Periodontology* 2016;87(4):385–94. [PubMed: 26537367]
38. Hayes C, Sparrow D, Cohen M, Vokonas PS, Garcia RI. The association between alveolar bone loss and pulmonary function: the VA Dental Longitudinal Study. *Annals of periodontology* 1998;3(1):257–61. [PubMed: 9722709]
39. Scannapieco F, Papandonatos G, Dunford R. Associations between oral conditions and respiratory disease in a national sample survey population. *Annals of Periodontology* 1998;3(1):251–56. [PubMed: 9722708]
40. Oksanen T, Kivimäki M, Pentti J, et al. Self-report as an indicator of incident disease. *J Annals of Epidemiology* 2010;20(7):547–54.
41. Senthilselvan A, Dosman JA, Chen Y. Relationship between pulmonary test variables and asthma and wheezing: a validation of self-report of asthma. *J Journal of Asthma* 1993;30(3):185–93.
42. Pitiphat W, Garcia RI, Douglass CW, Joshipura KJ. Validation of self-reported oral health measures. *J Journal of Public Health Dentistry* 2002;62(2):122–28.
43. Wilkins EM, McCullough PA. Clinical practice of the dental hygienist: Lea & Febiger; 1989.
44. Claramunt Lozano A, Sarrión Pérez MG, Gavalda Esteve C. Dental considerations in patients with respiratory problems. *J Clin Exp Dent*. 2011;3(3):e222–7.
45. Schallhorn R Understanding the Inter-relationship Between Periodontitis and Diabetes: Current Evidence and Clinical Implications. *Compendium of continuing education in dentistry (Jamesburg, NJ: 1995) 2016;37(6):368–70.*

46. Simone Taylor S, Hennekens C. Interrelationships of Periodontal Disease, Systemic Inflammation, and Cardiovascular Disease. *Ann Dentist Oral Disord* 2018;2:108.
47. Vedin O, Hagström E, Gallup D, et al. Periodontal disease in patients with chronic coronary heart disease: Prevalence and association with cardiovascular risk factors. *European journal of preventive cardiology* 2015;22(6):771–78. [PubMed: 24721691]
48. Singhrao SK, Kesavalu L, Crean S. Putative Association of Periodontitis with Alzheimer's Disease. *Advances in Alzheimer's Disease* 2017;5:183–96.
49. Ide M, Harris M, Stevens A, et al. Periodontitis and cognitive decline in Alzheimer's disease. *PLoS One* 2016;11(3):e0151081.
50. Ricardo AC, Athavale A, Chen J, et al. Periodontal disease, chronic kidney disease and mortality: results from the third national health and nutrition examination survey. *BMC nephrology* 2015;16(1):97. [PubMed: 26149680]
51. Kapellas K, Singh A, Bertotti M, et al. Periodontal and chronic kidney disease association: A systematic review and meta-analysis. *Nephrology* 2019;24(2):202–12. [PubMed: 29359889]
52. Shen T-C, Chang P-Y, Lin C-L, et al. Impact of periodontal treatment on hospitalization for adverse respiratory events in asthmatic adults: A propensity-matched cohort study. *European Journal of Internal Medicine* 2017;46:56–60. [PubMed: 28601370]

Table 1

Description of Selected Characteristics by Asthma and Chronic Obstructive Pulmonary Disorder (COPD) Status Adults (18 years or older) Behavioral Risk Factor Surveillance System Survey, 2016

	Asthma		COPD		Asthma + COPD		None		Chi-sq	Sig
	N	Wt %	N	Wt %	N	Wt %	N	Wt %		
ALL	38,817	10.9	19,819	4.0	13,494	2.8	315,087	82.3		
Sex									380.893	< 0.001
Female	24,790	58.3	11,483	52.5	9,379	63.7	175,308	50.5		
Male	14,027	41.7	8336	47.5	4115	36.3	139,779	49.5		
Race/Ethnicity									301.876	< 0.001
White	29,206	63.5	16,533	74.9	10,575	71.0	247,520	64.6		
African American	3,579	13.4	1,361	10.5	1,078	12.1	24,395	10.9		
Hispanic	2,632	13.7	613	7.0	607	9.1	21,233	15.7		
Other Race	2,828	7.8	1,028	6.2	1,027	6.1	17,687	7.3		
Missing	572	1.7	284	1.4	207	1.6	4252	1.5		
Age in Years									3093.911	< 0.001
18–34 years	8,351	38.5	720	9.6	624	11.0	45,309	27.9		
35–44 years	5,171	16.7	781	7.5	905	11.2	35,890	16.4		
45–54 years	6,568	16.3	2,106	15.2	2,023	18.2	50,511	17.5		
55–64 years	8,218	14.4	4916	24.6	3,838	26.3	70,475	17.4		
65–74 years	6,895	9.3	6,375	24.4	3,636	19.2	66,317	12.3		
75,+ Years	3614	4.8	4,921	18.7	2,468	14.2	46,585	8.6		
Past Year Dentist Visit									758.057	< 0.001
Yes	26,628	65.8	10,024	49.4	6,816	49.8	220,760	66.7		
No	11,917	33.3	9,510	49.1	6,519	49.0	91,975	32.6		
Missing	272	0.9	285	1.5	159	1.2	2,352	0.7		
Physical Activity									1988.102	
Yes	29446	77.0	11,054	56.0	7,068	54.4	242,721	77.2		
No	9,326	23.0	8,731	43.8	6,391	45.4	71,975	22.7		< 0.001
Missing	45	0.0	34	0.2	35	0.3	391	0.1		
Tobacco Use									3975.764	< 0.001
Current smoker	5,271	16.0	6,788	36.7	4,044	34.0	40,732	14.8		
Former smoker	10,497	22.7	8,826	40.2	5,499	36.4	88,850	24.2		
Never smoked	22,848	60.9	4,117	22.6	3,877	29.1	183,892	60.6		
Missing	201	0.4	88	0.5	74	0.5	1,613	0.5		

Note: Based on 387,217 adult respondents who had no missing values for questions on asthma or chronic obstructive pulmonary disease, age, sex, missing permanent teeth and those who had completed interviews in 2016, and were not in Guam or Puerto Rico. P-values are based on Rao-Scott chi-square tests.

ACOS, Asthma-COPD overlap syndrome; Wt., Weighted.

Table 2

Description of Selected Characteristics by Missing Permanent Teeth Categories Adults (18 years or older)
Behavioral Risk Factor Surveillance System Survey, 2016

	None		1–5 teeth		>=6 not all		All		Chisq	P-value
	N	Wt %	N	Wt %	N	Wt %	N	Wt %		
ALL	185,273	54.4	121,785	29.6	51,660	10.7	28,499	5.3		
Asthma/COPD									6067.764	< 0.001
Asthma	20,159	58.9	11,899	27.8	4,632	9.5	2,127	3.8		
COPD	4,126	24.3	5,443	28.6	5,621	26.6	4,629	20.4		
ACOS	3,002	26.2	3,794	28.5	3,821	27.5	2,877	17.9		
No Asthma No COPD	157,986	56.2	100,649	30.0	37,586	9.5	18,866	4.3		
Sex									45.813	< 0.001
Female	104,655	54.0	68,739	29.3	30,167	11.1	17,399	5.6		
Male	80,618	54.8	53,046	30.0	21,493	10.3	11,100	4.9		
Race/Ethnicity									856.910	< 0.001
White	147,501	54.9	93,784	28.0	39,561	11.1	22,988	6.0		
African American	11,024	44.9	10,678	34.4	6,084	14.8	2,627	6.0		
Hispanic	13,335	57.0	8,629	33.5	2,261	7.1	860	2.4		
Other Race	10,997	59.0	7,015	28.9	2,972	8.8	1,586	3.3		
Missing	2,416	51.5	1,679	30.6	782	11.3	438	6.7		
Age in Years									19240.031	< 0.001
18–34 Years	43,458	79.4	10,009	18.1	1,238	2.0	299	0.5		
35–44 Years	27,797	62.5	11,914	30.4	2,356	5.6	680	1.5		
45–54 Years	33,727	52.1	19,291	34.5	5,891	10.1	2,299	3.2		
55–64 Years	37,512	40.4	30,658	36.2	12,967	16.0	6,310	7.4		
65–74 Years	27,883	31.8	30,344	35.8	15,809	20.3	9,187	12.0		
75 or older	14,896	24.8	19,569	32.9	13,399	24.6	9,724	17.8		
Past Year Dentist Visit									4443.838	< 0.001
Yes	138,781	57.9	88,274	30.6	30,355	9.4	6,818	2.1		
No	45,302	47.5	32,873	28.0	20,802	13.2	20,944	11.2		
Missing	1,190	52.0	638	19.2	503	12.5	737	16.3		
Tobacco Use									7109.713	< 0.001
Current smoker	18,655	39.8	17,833	31.9	12,023	17.9	8,324	10.4		
Former smoker	42,961	43.2	38,586	33.1	20,350	15.4	11,775	8.3		
Never smoked	122,776	63.3	64,728	27.5	19,007	6.7	8,223	2.6		
Missing	881	51.7	638	30.4	280	11.9	177	6.1		

Based on 387,217 adult respondents who had no missing values for questions on asthma or chronic obstructive pulmonary disease, age, sex, missing permanent teeth and who had completed interviews in 2016 and were not in Guam or Puerto Rico.

Asterisks represent significant group differences by missing permanent teeth categories based on Rao-Scott chi-square tests. COPD, Chronic Obstructive Pulmonary Disorder; ACOS, Asthma-COPD overlap syndrome; Wt., Weighted.

Table 3

Odds Ratios (OR), Adjusted Odds Ratios (AOR) and 95% Confidence Intervals (CI) of Asthma/COPD Status from Multinomial Logistic Regression on Missing Permanent Teeth Categories (Reference Group: No Permanent Teeth Removed) Adults (18 years or older), Behavioral Risk Factor Surveillance System Survey, 2016

	1– 6 teeth		6 or more not all		All teeth Removed	
	OR [95% CI]	P-value	OR [95% CI]	P-value	OR [95% CI]	P-value
Model 1 – Unadjusted						
Asthma/COPD						
Asthma	0.88 [0.84 , 0.93]	< 0.001	0.95 [0.88 , 1.02]		0.85 [0.77 , 0.93]	< 0.001
COPD	2.21 [2.03 , 2.42]	< 0.001	6.45 [5.89 , 7.07]	< 0.001	10.97 [10.03 , 11.99]	< 0.001
ACOS	2.04 [1.85 , 2.26]	< 0.001	6.18 [5.59 , 6.83]	< 0.001	8.92 [8.02 , 9.93]	< 0.001
<i>No Asthma No COPD (reference)</i>						
Model 2 - Fully Adjusted Model						
	AOR [95% CI]	P-value	AOR [95% CI]	P-value	AOR [95% CI]	P-value
Asthma/COPD						
Asthma	1.01 [0.96 , 1.07]		1.13 [1.04 , 1.23]	0.0029	1.12 [1.004 , 1.26]	0.0433
COPD	1.21 [1.10 , 1.33]	< 0.001	1.74 [1.57 , 1.93]	< 0.001	2.04 [1.83 , 2.27]	< 0.001
ACOS	1.14 [1.03 , 1.27]	0.0154	1.70 [1.51 , 1.92]	< 0.001	1.82 [1.59 , 2.08]	< 0.001
<i>No Asthma No COPD (Reference)</i>						
Dental Visits Past Year						
Yes	1.09 [1.05 , 1.13]	< 0.001	0.87 [0.83, 0.92]	< 0.001	0.24 [0.22, 0.26]	< 0.001
No (Ref)						

Based on 387,217 adult respondents who had no missing values for questions on asthma or chronic obstructive pulmonary disease, age, sex, missing permanent teeth and who had completed interviews in 2016 and were not in Gaum or Puerto Rico. Asterisks represent significant group differences by Asthma COPD status in missing permanent teeth categories based on multinomial logistic regression on missing permanent teeth categories. Fully adjusted model controlled for the following variables: sex, age, race/ethnicity, marital status, education, income, health insurance, physical health, alcohol use, tobacco use, obesity, physical activity, region, and any dental visit in the past year.

COPD, Chronic Obstructive Pulmonary Disorder; ACOS, Asthma-COPD Overlap Syndrome