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Associations between tooth loss and ischemic heart disease and stroke in a national cohort

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ABSTRACT

Jaagosild, Tiina. M.P.H., Purdue University, May 2015. Associations between Tooth Loss and Ischemic Heart Disease and Stroke in a National Cohort. Major Professor: Gerald Hyner.

The association between oral health and cardiovascular disease (CVD) has been under vigorous investigation during the last decades. Consensus documents have stated the independent relationship between periodontal disease and subsequent tooth loss and CVD. Associations between tooth loss and chronic coronary heart disease (CHD), myocardial infarction (MI), and stroke have not been evaluated separately in a single nationwide cohort. This cross-sectional study used self-reported data from the Behavioral Risk Factor Surveillance System 2012 and was conducted to evaluate the association between the number of teeth lost due to caries or periodontal disease and the prevalence of CVD. The final cohort of 260,610 subjects consisted of persons 45 years of age and older; 41.50% of whom were 65 years old or older, 58.34% were female, and 81.86% were White. Logistic regression models were built separately for chronic CHD, MI, and stroke. After adjusting for age, race/ethnicity, sex, income, body mass index, diabetes, smoking status, alcohol usage, and diagnosis of another CVD, all models revealed a significant association between the number of teeth lost and the prevalence of chronic CHD, MI, and stroke. Although significant associations were present for the subjects who had lost 1-5 teeth, 6-31 teeth, and all teeth; the associations were the strongest in the latter group, where for chronic CHD *AOR* = 1.44, 95% CI [1.28, 1.63], for MI *AOR* = 1.86, 95% CI

[1.66, 2.10], and for stroke *AOR* = 1.46, 95% CI [1.29, 1.66]. Further adjustment for health insurance availability and dental care usage did not change the outcome. Subgroup analysis revealed similar outcomes for both sexes. Predictive associations were most significant in the range of 45-64 years of age. Tooth loss was independently associated with the prevalence of chronic CHD, MI, and stroke among people 45 years of age and older. The number of teeth lost could be used as an additional marker of an elevated cardiovascular risk in this age group.

Keywords: Tooth loss, chronic coronary heart disease, myocardial infarction, stroke

CHAPTER 1. INTRODUCTION

1.1 Introduction

Cardiovascular disease (CVD) has been the leading cause of death and disability in the U.S. and other economically highly developed countries for decades. Heart disease has been the leading cause of death for both men and women, and about 600,000 people have died of heart disease in the United States every year, equivalent to 1 in every 4 deaths (Murphy, Xu, & Kochanek, 2013). Stroke has been the fourth leading cause of death in the U.S., killing almost 130,000 Americans each year, equivalent to 1 out of every 19 deaths. On average, one American has died from stroke every four minutes (Go et al., 2014; Murphy et al., 2013). Traditional risk factors have not explained all of the risk for the incidence of cardiovascular disease events; therefore, an intense search for other potential risk factors remains (Helfand et al., 2004).

Periodontitis and tooth loss have been common in the U.S. Advanced gum disease has affected 4-12% of U.S. adults, and half of the cases of severe gum disease in the United States have been the result of cigarette smoking. One-fourth of U.S. adults 65 years or older have lost all of their teeth (Centers for Disease Control and Prevention [CDC]. Oral Health. 2011).

Several authors have considered periodontitis a leading cause of tooth loss in the U.S. and evaluated tooth loss as a surrogate marker of past periodontitis (Bahekar, Sing,

Saha, Molnar, & Arora, 2007; Joshipura, Hung, & Rimm, 2003; Lafon, Pereira, & Dufor, 2014; Lockhart et al., 2012). In 2004, Copeland et al. analyzed the predictors of tooth loss in two U.S. middle-aged adult populations and concluded that the incidence, rates, and predictors of tooth loss varied considerably by population and by sex. In their study, significant predictors of tooth loss were: percent of teeth with restorations, mean probing pocket depth score, age, tobacco and alcohol use, male sex, and number of teeth present. Holm-Pedersen, Lang, and Muller (2007) noted in their review article that while teeth in adolescents and youth might have been lost primarily because of dental caries, studies revealed that tooth loss later in life may be mostly due to periodontal infections.

Joshipura, Douglass, and Willett (1998) have described five pathways for the relationship between tooth loss and CVD: 1) common risk factors for dental and cardiovascular disease, 2) infection-inflammatory pathway, 3) diet pathway, 4) psychosocial pathway, and 5) healthy behavior pathway (Figure 1).

Most of the epidemiological studies examining the associations between tooth loss and cardiovascular disease have focused on evaluating links between periodontal disease as a source of chronic inflammatory process, subsequent tooth loss, and CVD, while controlling for most common risk factors for CVD (Lockhart et al., 2012; Tonetti & Van Dyke, 2013). Since 2010, at least three consensus documents about the associations of periodontal health and cardiovascular disease have been published (Lockhart et al., 2012; Sanz, D'Aiuto, Deanfield, & Fernandez-Aviles, 2010; Tonetti & Van Dyke, 2013). Chronic oral infections such as caries and periodontitis, and subsequent tooth loss, have been shown to have strong correlations with not only CVD morbidity, but also mortality (Holmlund, Holm, & Lind, 2010; Xu & Lu, 2011).

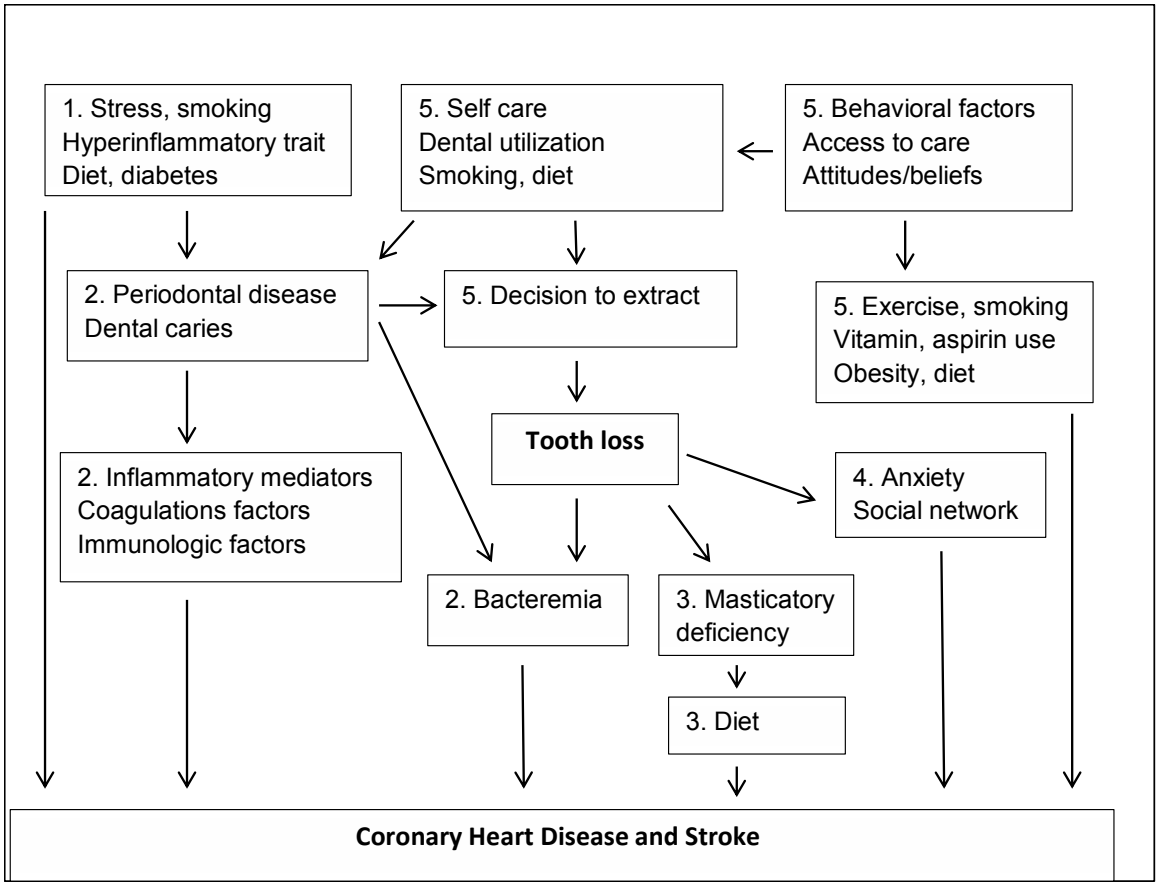

Figure 1. Pathways for the relationship between tooth loss and cardiovascular disease: 1) common risk factors for dental and cardiovascular disease, 2) infection-inflammation pathway, 3) diet pathway, 4) psychosocial pathway, 5) healthy behavior pathway. Adapted from "Tooth loss and cardiovascular disease relationship," by K.J. Joshipura, C.W. Douglass, and W.C. Willett, 1998, *Annals of Periodontology, 3*, p.177. Copyright by the American Academy of Periodontology.

The U.S. Preventive Services Task Force (Helfand, Buckley, Freeman, Fu, & Rogers, 2004) stated that periodontal disease and subsequent tooth loss were predictive of CVD events (coronary heart disease [CHD] events, stroke, and death due to those diseases), but overall strength of evidence showing a causative link was poor. In 2012, an American

Heart Association Scientific Statement concluded that observational studies supported an association between periodontal disease and atherosclerotic vascular disease independent of known confounders (Lockhart et al., 2012).

The estimated level of cardiovascular disease risk associated with periodontal disease or tooth loss varied in different cohorts and meta-analyses. Bahekar et al. (2007) concluded in their meta-analysis that the prevalence of CHD was significantly greater among individuals with periodontal disease than in those without, *OR* = 1.59, 95% CI [1.3, 1.9]. In the same study, when the relationship between the number of teeth and incidence of CHD was analyzed, cohort studies showed 1.24, 95% CI [1.14,1.36], times increased risk of development of CHD in patients with less than 10 teeth.

One of the few meta-analyses that assessed the association between periodontal disease/tooth loss and CHD and stroke separately (Janket, Baird, Chuang, & Jones, 2003), concluded that among individuals ≤ 65 years of age, relative risk (RR) for cardiovascular disease (CHD and stroke) was 1.44, 95% CI [1.2, 1.73]; for stroke alone it was 2.85, 95% CI [1.78, 4.56]. The risk was lower among older individuals. Dietrich, Jimenez, Krall Kaye, Vokonas, and Garcia (2008) also showed that periodontitis was associated with CAD among men < 60 years of age, but not older, *HR* = 2.12, 95% CI [1.26, 3.60]. In the same study, edentulous men tended to have a higher risk of CAD than dentate men, *HR* = 1.72, 95% CI [1.03, 2.85], independent of confounders. Lafon et al. (2014) demonstrated that the risk of stroke was significantly increased by the presence of periodontitis, *RR* = 1.63, 95% CI [1.25, 2.00] and tooth loss was a risk factor for stroke, *RR* = 1.39, 95% CI [1.13, 1.65].

A PubMed search revealed two studies that have analyzed associations between tooth loss and heart disease in CDC's Behavioral Risk Factor Surveillance System (BRFSS) databases. Okoro et al. (2005), analyzing data from 1999-2002, demonstrated a significant association between the extent of tooth loss and heart disease. The second study by Wiener and Sambamoorthi (2014) confirmed the previous findings. In the latter study, edentulous people over 50 years of age were more likely to report coronary heart disease, adjusted odds ratio *(AOR)* = 1.85, 95% CI [1.71, 2.01] after controlling for a comprehensive set of risk factors. It is notable that the cohort who had visited a dentist in the past year had a reduced risk of coronary heart disease in Wiener and Sambamoorthi's (2014) study. The latter finding supports the idea that periodontal disease and subsequent tooth loss are not independent risk factors for coronary heart disease, but rather markers of disadvantaged lifestyle and psychosocial status.

In the international cohort of 15,828 subjects with CHD, it was found that less tooth loss was associated with lower levels of glucose, lower low density lipoprotein levels, lower systolic blood pressure, and decreased odds of smoking and diabetes (Vedin et al., 2014). Tooth loss was considered a result of long-term chronic exposure to etiological factors that are at least partly common to both CHD and periodontal disease. Vedin et al. (2014) concluded that because tooth loss can have causes other than periodontal disease, such as caries, trauma and deliberate extractions, tooth loss should not be treated strictly as an indicator of periodontal disease, but rather a marker of overall dental health and possibly even a marker of general health, socioeconomic factors and psychosocial status.

Linden, Lyons & Scannapieco (2013) suggested that as CVD and oral diseases share common risk factors, periodontitis may be a phenotype of low socioeconomic status reflecting factors such as smoking, poverty and low education, and oral diseases develop in parallel with other diseases that reflect a disadvantaged lifestyle. Support for the latter argument comes from studies where no independent association between periodontal disease and subsequent cardiovascular disease was found, as in a homogenous, high-income, male physician's cohort (Howell, Ridker, Ajani, Hennekens, & Christen, 2001).

Gilbert, Duncan, and Shelton (2003) demonstrated in the Florida Dental Care Study, that African Americans and persons with lower socioeconomic status reported more dental symptoms, but were less likely to obtain dental care. When they did receive care, they were more likely to experience tooth loss and less likely to report that a dentist had discussed alternative treatments with them. Jimenez, Dietrich, Shih, Li, and Joshipura (2009) have reported that no association between poverty and number of teeth was observed among Blacks and Mexican Americans in their study, while the poorest Whites were missing 39% more teeth than the most affluent Whites. They also concluded that dental care utilization exhibited a consistent relationship with tooth loss among all racial/ethnic groups.

As of 2015, there was no recent nationwide study that assessed the relationship between tooth loss and CHD and stroke separately in the same cohort plus evaluated whether access to health care and actual usage of dental care would influence that association. Therefore, the purpose of this study was to determine the strength of associations between tooth loss and CHD and stroke separately in different age groups in

a single nationwide cohort, and whether access to health care and dental care utilization had any influence on this association.

Study hypotheses were: 1) Among the cohort of subjects who are 45-54 years old, 55-64 years old, and age 65 and older, there is a significant association between tooth loss (people who have lost one to five, six or more teeth or who are edentulous) and chronic CHD and myocardial infarction (MI) prevalence, controlling for a comprehensive set of covariates; 2) Among the cohort of subjects who are 45-54 years old, 55-64 years old, and age 65 and older, there is a significant association between tooth loss (people who have lost one to five, six or more teeth or who are edentulous) and stroke prevalence, controlling for covariates; 3) When controlling for dental care usage and health insurance availability, this association between the number of teeth lost and CHD and stroke is attenuated or completely lost.

CHAPTER 2. METHODS

2.1 Description of the Database and Study Sample

The Behavioral Risk Factor Surveillance System (BRFSS) is an annual, on-going, landline and cellular telephone health survey system in the U.S., the largest nationwide program of its kind in the world. The BRFSS is a collaborative project of the Centers for Disease Control and Prevention (CDC) with U.S. states and territories, and it is designed to measure behavioral risk factors for the adult population (18 years of age and older) living in households (CDC. BRFSS). In 2012 the median survey response rate for all states was 45.2%, and the final core module consisted of information obtained from 475,687 subjects (CDC. BRFSS 2012. Summary Data Quality Report).

The incidence of cardiovascular disease rises steeply among middle-aged adults (Mozaffarian et al., 2015); therefore, the current study examines the cohort of subjects 45 years and older. In the BRFSS 2012, 342,695 subjects were 45 years and older.

2.2 Definitions of Variables

Dependent variables included dichotomous responses to the following questions: 1) "Has any health professional ever told you that you had a heart attack, also called a myocardial infarction?"; 2) "Has any health professional ever told you that you had angina or coronary heart disease?"; 3) "Have you ever been told that you had a stroke?"

Number of teeth removed, the independent categorical variable, was obtained from responses to the question, "How many of your permanent teeth have been removed because of tooth decay or gum disease?" with possible answers: 1) none; 2) 1-5; 3) 6 or more, but not all; 4) all. Covariates were chosen from established cardiovascular risk factors measured in the BRFSS 2012 survey: 1) age (45-54 years, 55-64 years, and ≥ 65 years); 2) race/ethnicity (White, Black, Hispanic, other); 3) sex (male/female); 4) income (< $25,000 per family per year, $25,000 < $35,000, $35,000 < $50,000, $50,000 < $75,000, ≥ $75,000); 5) Body Mass Index (normal BMI < 25, overweight or obese BMI ≥ 25); 6) diabetes (no diabetes/ prediabetes, gestational diabetes or diabetes); 7) smoking status (never smoked, current smoker, past smoker); 8) alcohol usage above the healthy norm (men having more than two drinks per day, women having more than one drink per day); 9) diagnosis of another (chronic CHD, MI, stroke) CVD (yes/no); 10) health insurance availability (yes/no); and 11) dental care usage (visit to the dental office in the last year, no visit in the last year).

2.3 Data Analysis

This study was a secondary data analysis employing a cross-sectional design. The subjects who missed or refused to respond to items, or were not sure about their response, were excluded from the final database. Listwise deletion was implemented. The number of subjects for whom all data were available was 260,610.

Descriptive analysis was performed on the final cohort. Logistic regression analysis was implemented to calculate associations between the number of missing teeth and chronic CHD, MI, and stroke, after controlling for a comprehensive set of covariates.

Separate baseline models were built for each of the abovementioned outcome variables. Additional models were built for separate age groups and sex. Final weight was added to the models to make the estimates representative for the national population. Overall model fit was assessed with receiver operator characteristic curve (ROC) diagnostics. For all analyses, p values < .05 were considered statistically significant. Statistical analysis was performed using Stata 13.1 (StataCorp, College Station, TX).

CHAPTER 3. RESULTS

3.1 Participant Characteristics

The final cohort of 260,610 subjects consisted of persons 45 years of age and older; 41.50 % of them were ≥ 65 years old, 58.34% were female, and 81.86% were White. Among those who were ≥ 65 years old, 63.63% were female. Descriptive statistics are represented in Appendix A. The number of teeth lost was the highest in the ≥ 65-year age group: 34.62% had lost 1-5 teeth, 23.36% had lost 6-31 teeth, and 16.04% had lost all of their teeth. Among the subjects 45-54 years old, 3.60% had lost all of their teeth, and among 55-64 year olds 7.28% had lost all teeth (Table 1).

As chronic CHD or angina and MI are separate manifestations of atherosclerotic heart disease, 49.72% of subjects reported having being told that they have both chronic CHD and MI. Sixteen percent of subjects reported the diagnosis of stroke and chronic CHD simultaneously.

Table 1. Number of Teeth Lost by Age Group

Age	Number of teeth lost *N* (%)			
	None	1 to 5	6 -31	All
45-54	36,171 (52.43)	22,968 (33.29)	7,371 (10.68)	2,483 (3.60)
55-64	33,245 (39.83)	30,555 (36.60)	13,600 (16.29)	6,076 (7.28)
≥ 65	28,093 (25.98)	37,437 (34.62)	25,263 (23.36)	17,348 (16.04)

3.2 Associations between Coronary Heart Disease, Stroke, and Tooth Loss

All three baseline logistic regression models built in this study revealed a significant association between the number of permanent teeth lost and CHD and stroke. For chronic CHD, $\chi^2(20) = 9616.29$, $p < .001$; for MI $\chi^2(20) = 9502.00$, $p < .001$; for stroke $\chi^2(20) = 3869.12$, $p < .001$. The results of the logistic regression analyses are displayed in Appendix B. There was a significant association ($p < .001$) between the number of teeth lost and chronic CHD and MI in all tooth loss groups, but the association was most prominent in the group with all permanent teeth lost (for chronic CHD *AOR* = 1.44, 95% CI [1.28, 1.63]; for MI *AOR* = 1.86, 95% CI [1.66, 2.10]).

Association between stroke prevalence and the number of teeth lost was significant among the subjects who have lost 6-31 teeth, *AOR* = 1.40, 95% CI [1.24, 1.59], and all of their teeth, *AOR* = 1.46, 95% CI [1.29, 1.66], but not in the group with 1-5 teeth lost, *AOR* = 1.11, 95% CI [0.99,1.22]. Overall model fit was assessed with ROC (AUC) diagnostics. This assessment revealed a good model fit for all three models. For CAD model AUC = .84, for MI model AUC = .86, and for stroke model AUC = .77.

Adding the variables measuring the availability of health insurance and dental visit during the last year to the model did not change the magnitude of the association between the tooth loss and cardiovascular disease outcomes in any of the models.

Although males had significantly higher odds for chronic CHD and MI compared to females in baseline models, the subgroup analysis by sex showed similar associations between tooth loss and CVD in both sexes.

Subgroup analysis for three different age groups revealed that the association between the teeth lost and CVD was the weakest in the oldest age group (age ≥ 65). In

the ≥ 65 age group significance was not demonstrated for stroke among subjects who had lost 1-5 or 6-31 teeth, but significance did exist among those with complete tooth loss (*AOR* = 1.24, 95% CI [1.07,1.45]. In age groups 45-54 and 55-64, odds of having chronic CHD, MI, or stroke were > 1.5 among those who had lost either 6-31 or all of their teeth. The strongest association between the tooth loss and MI and stroke were among those who had lost all teeth, *AOR* = 1.98, 95% CI [1.56, 2.51] for myocardial infarction and *AOR* = 2.17, 95% CI [1.51, 3.12] for stroke.

3.3 Covariates

There were several interesting findings regarding the covariates' association with CVD, exhibited in Appendix C. Having one type of CVD was the strongest risk factor for another CVD diagnosis, as anticipated. Diabetes was a significant risk factor for CHD and stroke in all baseline models, and also in all subgroup models. The association between chronic CHD and diabetes was the strongest among the subjects who were 45-54 years old, *AOR* = 2.67, 95% CI [2.06, 3.42]. In all the models alcohol consumption beyond a moderate amount had a protective effect against CVD, for example in the baseline model for chronic CHD *AOR* = 0.81, 95% CI [0.67, 0.93]. Current smokers had significantly higher odds for CVD; for MI *AOR* = 1.7, 95% CI [1.57, 1.94]. Income had a significant association with the outcome variables in each model, including subgroup models, with the highest cardiovascular disease risk among those with yearly household income < $25,000. The risk of both chronic CHD and MI for Black and Hispanic people was significantly lower compared to the Whites in this cohort; the risk of stroke was higher for the Black cohort, *AOR* = 1.3, 95% CI [1.17, 1.48]. Having had a dental visit

during the last year was protective against MI and stroke, for MI *AOR* = 0.87, 95% CI [0.80, 0.94].

CHAPTER 4. DISCUSSION

4.1 Discussion

The current study was the first study, with 260,610 subjects 45 years and older, that investigated associations between tooth loss and chronic CHD, MI, and stroke separately in the same nationwide cohort. The hypothesis that chronic CHD, MI, and stroke were all significantly associated with tooth loss among subjects who are older than 45 years was supported and thus these findings added to the body of evidence that the status of oral health reflected the level of cardiovascular risk.

The associations between tooth loss and CVD found in this study were of the same magnitude as in previous studies, with increased CVD risk in proportion to the extent of tooth loss. Contrasted with the results from the Janket et al. (2003) meta-analysis, which found the risk for stroke considerably higher than the risk for CHD among subjects with periodontal disease and subsequent tooth loss, the current study demonstrated that the risk for CHD and stroke were similar. A possible explanation for the latter finding was that the tooth loss and stroke study in the meta-analysis involved a Native American cohort whose health behavior and risks differed from the mainly White cohort.

Only a few studies have analyzed the association between tooth loss and CHD among males and females separately. Hung et al. (2004) found in their prospective 10 year study that males with 0-10 teeth at baseline had significantly higher risk for CHD in comparison to males with 25-32 teeth, *RR* = 1.36, 95% CI [1.11, 1.67]; the RR in the female cohort with the same tooth loss status was 1.79, 95% CI [1.31, 2.05]. In the current study, the association between the number of teeth lost and CVD risk was similar in the male and female cohort. For those who had lost all their teeth, *OR* = 1.8, 95% CI [1.56, 2.20] for MI, compared with the subjects with all teeth.

It is important to note that previous studies which evaluated the association between periodontal disease, subsequent tooth loss, and CVD demonstrated a weaker or even absent association among subjects who were over 60 or 65 years old (Dietrich et al., 2008; Jimenez, Krall, Garcia, Vokonas, & Dietrich, 2009; Xu & Lu; 2011). The current study concentrated on tooth loss due to caries and periodontal disease and revealed the same results: the odds of both CHD and stroke were the highest among subjects who lost 6 or more teeth and were 45-64 years old. Significant, but weaker associations, between tooth loss and risk for CVD were found among the cohort of 65 years and older, as well. Several explanations could be given for the fact that the association between the tooth loss and cardiovascular disease was weaker in older age than among younger. First, it was more likely that people in the older age group might not have remembered the exact reason for their tooth loss, and recall bias might be present. Second, although tooth loss has become more prevalent at advanced age, it could be speculated that major tooth loss might have occurred much earlier in life, thus eliminating the source of constant inflammatory drive in the body (Dietrich et al., 2008). Third, the theory of a common

proinflammatory susceptibility has hypothesized that some individuals have traits to develop inflammatory periodontal disease and atherosclerosis in parallel at younger age (Cotti, Dessi, Piras, & Mercuro, 2011; Dietrich et al., 2008). Fourth, at older age, other risk factors like hypertension and obesity might have been more prevalent and played a stronger causative factor/role for the development of CHD and stroke (Caplan et al., 2006).

In the current study, Hispanics and African Americans had a lower risk for cardiovascular disease than Whites. The reason for this finding was not clear; one speculation was that Hispanics and African Americans who were included in the BRFSS 2012 dataset were healthier than the average representative of this subgroup. Alcohol consumption above the moderate, safe amount per CDC (one drink for women and two drinks for women per day) offered protection against CVD in this study (CDC. Alcohol and Public Health). This finding was in concordance with the Corrao, Bagnardi, Zambon, & Vecchia (2004) meta-analysis, which observed the protective effect of alcohol up to 72 g of ethanol per day against CVD. It is likely that those who responded to the BRFSS questionnaire only slightly exceeded the safe alcohol amount.

In the current study, household income was strongly associated with the diagnosis of CVD if the yearly household income was under $25,000. Socioeconomic status accounted for 50% of variation in the prevalence of periodontitis in the study conducted by Hobdell et al. (2003). The hypothesis that health insurance availability and a visit to the dentist's office during the last year would attenuate the association between tooth loss and risk of CVD was not supported in the current study. Those subjects who had visited the dental office during the last year had a significantly lower risk of CHD and stroke.

This finding was consistent with Wiener and Sambamoorthi's (2014) findings from the BRFSS 2010 dataset.

4.2 Limitations

The current study had several limitations. First, the data in the BRFSS dataset were self-reported; thus, report bias was likely to be present. Second, the study was cross-sectional and therefore did not allow any conclusions about causality to be drawn. Third, in this study, Black and Hispanic people were underrepresented, especially in the age group above 65; thus, inferences drawn for this population group might not be accurate. Fourth, established risk factors for CVD, such as hypertension and hypercholesterolemia, could not be added to the regression models because they were not assessed in the survey. Data about physical activity as a risk factor were omitted from the analysis because the question asked in the survey did not allow true discrimination between sedentary and active lifestyles. Fifth, the BRFSS 2012 questionnaire asked several questions about the intake of certain food groups, but due to the complexity of the topic, it was not possible to create meaningful covariates for the current study. Unhealthy patterns of nutrition might not only have been the consequence of tooth loss, but also the causal factors for both tooth loss and CVD (Joshipura et al., 1998).

Tooth loss reflects the ultimate outcome of oral disease over the course of life, and it is related to complex behavioral and socio-economic factors (Holm- Pedersen et al., 2007; Ylöstalo, Järvelin, Laitinen, & Knuutila, 2006). Although the current study demonstrated independent significant associations between tooth loss and CVD, it was evident that selected covariates did not cover all of the suggested multifaceted pathways

for the relationship between tooth loss and CVD (Joshipura et al., 1998), thus it was not possible to exclude the missing confounder.

4.3 Recommendations for Future Studies

Future studies exploring the links between oral health and CVD should address not only the established set of cardiovascular risk factors, dietary and physical activity habits, but also behavioral covariates and psychological characteristics, such as life satisfaction, as suggested by Ylöstalo et al. (2006), and parents' socioeconomic class, used by Mendall et al. (2000).

Studies have demonstrated that periodontal therapy reduces systemic inflammatory markers, but there has been no evidence that therapy has translated into reduced CVD events (Lockhart et al., 2012). Due to the fact that tooth loss is a marker of life long health habits, it would be very challenging to conduct randomized controlled studies addressing that question.

The minority population in the U.S. faces a variety of health challenges. The health behaviors of various groups differ substantially; thus, a study addressing the associations of tooth loss and CVD among minorities would be recommended.

4.4 Conclusion

The finding of the current study that tooth loss was independently associated with coronary heart disease and stroke, reemphasizes that self-reported number of teeth should be used as an additional available and affordable tool for coronary heart disease and/or stroke risk assessment both in research and medical providers' office, and it is of

particular importance in the age group 45-64. This study confirmed earlier findings that good oral hygiene including both caries and periodontitis prophylaxis and care should be promoted as preventive measures against heart disease and stroke. Access to periodic dental care in all age groups has the potential to reduce the prevalence of CVD nationwide.

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APPENDICES

Appendix A Description of the Final Cohort (N = 260,610)

Characteristic	N	%
Age		
45-54	68,993	26.47
55-64	83,476	32.03
≥65	108,141	41.50
Sex		
Male	108,557	41.66
Female	152,033	58.34
Race or ethnicity		
White	213,323	81.86
Black	20,504	7.87
Hispanic	13,679	5.25
Other	13,104	5.03
N of teeth removed		
None	97,509	37,42
1-5	90,960	34.90
6-31	46,234	17.74
All	25,907	9,94
Annual household income		
< $25,000	78,973	30.30
$25,000 < $34,000	31,106	11.94
$35,000 < $49,000	39,330	15.09
$50,000 < $74,000	41,066	15.76
≥ $75,000	70,135	26.91
Smoking status		
Never	132,111	50.69
Former	89,468	34.33
Current	39,031	14.98

Appendix A continued

BMI		
< 25	83,904	32.20
≥ 25	176,706	67.80
Reported diabetes	47,640	18.28
Reported excess alcohol usage	14,127	5.42
Diagnosed with MI	20,271	7.78
Diagnosed with chronic CHD	21,806	8.37
Diagnosed with stroke	12,954	4.97

Appendix B Association between the Number of Teeth Lost and Cardiovascular Disease (Comparison with no Missing Teeth)

		All subjects (N = 260,610)	Age 45-54 (N = 68,993)	Age 55-64 (N = 83,476)	Age ≥65 (N = 108,141)
		AOR (95%CI)			
N of teeth lost	Outcome CVD				
1-5					
	CHD[a]	1.34 [1.23, 1.45]*	1.45 [1.16, 1.82]*	1.23 [1.05, 1.43]*	1.25 [1.13, 1.39]*
	MI[b]	1.17 [1.07, 1.28]*	1.13 [0.89, 1.40]	1.32 [1.1, 1.56]*	1.03 [0.92, 1.15]
	Stroke[c]	1.11 [0.99, 1.22]	1.21 [0.94, 1.56]	1.07 [0.87, 1.31]	0.97 [0.85, 1.10]
6-31					
	CHD[a]	1.54 [1.38, 1.73]*	1.55 [0.99, 2.43]	1.56 [1.29, 1.88]*	1.41 [1.24, 1.59]*
	MI[b]	1.51 [1.36, 1.68]*	1.56 [1.19, 2.05]*	1.86 [1.52, 2.27]*	1.26 [1.11, 1.42]*
	Stroke[c]	1.40 [1.24, 1.59]*	1.54 [1.12, 2.10]*	1.66 [1.32, 2.09]*	1.12 [0.97, 1.30]
All					
	CHD[a]	1.44 [1.28, 1.63]*	1.78 [1.20, 2.64]*	1.70 [1.36, 2.11]*	1.34 [1.17, 1.54]*
	MI[b]	1.86 [1.66, 2.10]*	1.91 [1.34, 2.74]*	1.98 [1.56, 2.51]*	1.73 [1.51, 1.99]*
	Stroke[c]	1.46 [1.29, 1.66]*	2.17 [1.51, 3.12]*	1.71 [1.33, 2.20]*	1.24 [1.07, 1.45]*

Note. *$p < 0.01$

CHD = chronic coronary heart disease; MI = myocardial infarction; *AOR* = adjusted odds ratio; CI = confidence interval.

[a] Adjusted for myocardial infarction, stroke, sex, diabetes, BMI, alcohol consumption, race, age, smoking status, income.

[b] Adjusted for chronic coronary heart disease, stroke, sex, diabetes, BMI, alcohol consumption, race, age, smoking status, income.

[c] Adjusted for chronic coronary heart disease, myocardial infarction, sex, diabetes, BMI, alcohol consumption, race, age, smoking status, income.

Appendix C Results of the Baseline Multivariate Logistic Regression Analyses. Associations between the Independent Variables and Chronic CHD, MI, and Stroke in BRFSS 2012

	Chronic Coronary Heart Disease (CHD)	Myocardial Infarction (MI)	Stroke
		AOR (95% CI)	
Diagnosis of stroke	1.78 [1.69, 1.87]*	3.54 [3.12, 4.02]*	NA
Diagnosis of CHD	NA	17.50 [16.21, 18.87]*	1.72 [1.52, 1.94]*
Diagnosis of MI	17.29 [16.01, 18.67]*	NA	3.43 [3.02, 3.89]*
Male (*vs* Female)	1.42 [1.32, 1.52]*	2.02 [1.87, 2.17]*	1.04 [0.96, 1.12]
Diabetes	1.85 [1.70, 2.00]*	1.58 [1.46, 1.72]*	1.54 [1.41, 1.68]*
BMI ≥ 25	1.15 [1.06, 1.24]*	1.17 [1.08, 1.27]*	1.00 [0.92, 1.09]
Excess alcohol	0.81 [0.70, 0.93]*	0.72 [0.62, 0.84]*	0.81 [0.68, 0.98]*
Teeth removed			
1-5 *vs* none	1.34 [1.23, 1.45]*	1.17 [1.07, 1.28]*	1.10 [0.99, 1.22]
6-31 *vs* none	1.54 [1.38, 1.73]*	1.51[1.36, 1.68]*	1.41 [1.24, 1.59]*
All *vs* none	1.45 [1.28, 1.63]*	1.86[1.66, 2.10]*	1.46 [1.29, 1.66]*
Race/ethnicity			
Black *vs* White	0.82 [0.73, 0.93]*	0.78 [0.68, 0.88]*	1.32 [1.17, 1.48]*
Hispanic *vs* White	0.71 [0.61, 0.84]*	0.81 [0.67, 0.97]*	0.65 [0.54, 0.79]*
Other *vs* White	0.94 [0,74, 1.20]	0.90 [0.74,1.10]	1.37 [1.12, 1.66]*
Age			
55-64 (*vs* 45-54)	1.81 [1.62, 2.02]*	1.30 [1.16, 1.45]*	1.45 [1.28, 1.63]*
≥ 65 (*vs* 45-54)	2.60 [2.30, 2.90]*	1.73[1.56, 1.93]*	2.19 [1.12, 1.66]*
Smoking status			
Current *vs* never	1.16 [1.05, 1.29]*	1.74 [1.57, 1.94]*	1.34 [1.21, 1.50]*
Former *vs* never	1.30 [1.20, 1.40]*	1.35 [1.24, 1.46]*	1.08 [0.99, 1.18]

Appendix C continued

Income (*vs* ≥ $75,000)			
< $25,000	1.24 [1.10, 1.38]*	2.21 [1.98, 2.46]*	2.56 [2.24, 2.93]*
$25,000 < $35,000	1.02 [0.90, 1.15]	1.77 [1.55, 2.02]*	1.68 [1.44, 1.96]*
$35,000 < $50,000	1.00 [0.88, 1.13]	1.55 [1.36, 1.75]*	1.48 [1.27, 1.72]*
$50,000 < $75,000	0.98 [0.88, 1.10]	1.40 [1.24, 1.58]*	1.17 [0.99, 1.37]

Note. * p < .005

CHD = Chronic CHD; MI = myocardial infarction; *vs* = *versus*; *AOR* = adjusted odds ratio; NA = not applicable