รายงานวิจัยฉบับสมบูรณ์

โครงการโมเดลประเมินความเสี่ยงต่อการสูญเสียฟันในผู้ใหญ่

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มิถุนายน 2560

สัญญาเลขที่ TRG5880169

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Abstract

Project Code: TRG 5880169

Project Title: Risk assessment model for tooth loss in adults

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Project Period: 2 years (1 July 2015-30 June 2017)

Objectives: The purpose of this study is to develop a risk assessment model for tooth loss in using multi-dimensional risk assessment framework.

Methods:

Phase I: Potential risk indicators were identified based on literature reviews and an analysis of predictors for 10-year incidence of tooth loss in the Dental Atherosclerosis Risk in Communities (ARIC) study. A set of risk indicators or protective factors potentially associated with tooth loss outcome can be grouped into four domains: 1) clinical oral conditions 2) oral health behaviors and perception 3) environmental and socio-demographic factors 4) general medical conditions. Performance of the tooth loss prediction models based on the proposed sets of items was assessed.

Phase II: Cross-sectional oral health survey was conducted in Thai adults aged 35 and older (n=900). A web-based survey program was used for the data collection. Factors correlated with oral health status, including the number of remaining teeth at baseline and self-reported tooth loss in the past 5 years were examined.

Results:

Phase I: Of the 3,522 study subjects with complete data, 85.3% were white and 60.0% were female, with an average age of 61.3 ± 5.3 years at baseline. The majority of participants had 23 teeth on average at enrollment. At follow-up, 38% reported having lost ≥1 tooth. In the final model, periodontitis, extent of plaque, infrequent/symptomatic dental visits, and low income were independent predictors of 10-year incidence of tooth loss, together with a greater number of teeth and a greater number of filled root surfaces at baseline. The area under the receiver operating characteristic (AUC) curve was 0.63, signifying modest accuracy in predicting risk of tooth loss.

Phase II: Preliminary analysis was conducted for 900 participants in this phase. Study participants consisted of 72% female with an average age of 50.36 ± 8.03 years old. About one fourth of study participants were Muslim. The average number of remaining teeth

per person decreased with increased age: 27, 24, and 20 per person for 35-<45, 45-<55, and ≥55 years old respectively. About 77% of study participants had retained ≥ 20 teeth. Older age, Muslim, low education, having desert between meal, less frequent tooth brushing, periodontal disease, retained roots and root decays were significantly associated with greater likelihood of having fewer teeth. About 74% had dental service use in the past 5 years. Among individuals who reported extraction experience in the past 5 years, 66%, 21%, and 13% lost 1-2 teeth, 3-4 teeth, and 5 or more teeth, respectively. The greater number of self-reported tooth loss (≥ 3 teeth) was associated with increased age, Muslim, low education, smoking, less frequent tooth brushing, periodontal disease, and coronal decays.

Conclusion and further research: Many factors are associated with risk of having fewer teeth and greater number of tooth loss. Periodontal disease a significant risk factors for tooth loss in two study populations. However, the role of root caries, dental service use, smoking, and social inequalities in tooth loss were different between two study populations. For further analysis, we aim to 1) use factor analysis for risk items reduction; 2) test the longitudinal validity and accuracy of the proposed risk model; and 3) transfer the revised tool to a web-based system.

Keywords: Tooth loss, Periodontal disease, Dental caries, Adults

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ชื่อโครงการ: โมเดลประเมินความเสี่ยงต่อการสูญเสียฟันในผู้ใหญ่

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วัตถุประสงค์: เพื่อพัฒนาโมเดลสำหรับการประเมินความเสี่ยงต่อการสูญเสียฟันในผู้ใหญ่โดยใช้แนวคิดการประเมินปัจจัยความเสี่ยงในหลายมิติ

วิธีการ:

ระยะที่ 1: ปัจจัยที่อาจใช้ทำนายโอกาสการสูญเสียฟันจะได้จากการทบทวนวรรณกรรมและการวิเคราะห์ข้อมูลอุบัติการณ์การสูญเสียฟันในระยะเวลา 10 ปีของการศึกษาก่อนหน้า (The Dental Atherosclerosis Risk in Communities (ARIC) study) ปัจจัยเสี่ยงและปัจจัยป้องกันสามารถแบ่งออกได้เป็น 4 มิติดังนี้ 1) ปัจจัยทางคลินิกหรือสภาวะสุขภาพช่องปาก 2) ปัจจัยเชิงพฤติกรรมและการรับรู้เกี่ยวกับสุขภาพช่องปาก 3) ปัจจัยด้านสิ่งแวดล้อมและสังคม 4) ปัจจัยด้านสุขภาพร่างกาย ทำการวิเคราะห์หาความสามารถในการทำนายโอกาสการสูญเสียฟัน ของโมเดลต่าง ๆ

ระยะที่ 2: การสำรวจสภาวะสุขภาพช่องปากภาคตัดขวางในประชากรไทยอายุตั้งแต่ 35 ปีขึ้นไปจำนวน 900 คน โดยการบันทึกข้อมูลผ่านเวปโดยใช้โปรแกรมที่ออกแบบมาเพื่อการศึกษานี้ ทำการวิเคราะห์หาปัจจัยที่เกี่ยวข้องกับสภาวะสุขภาพช่องปาก รวมถึงจำนวนฟันธรรมชาติที่เหลืออยู่ และประสบการณ์การสูญเสียฟันในระยะ 5 ปีที่ผ่านมา

ผลการศึกษา:

ระยะที่ 1: จากอาสาสมัครซึ่งมีข้อมูลสมบูรณ์จำนวน 3,522 คน ร้อย 85.3 เป็นคนผิวขาว และร้อยละ 60.0 เป็นเพศหญิงที่มีอายุเฉลี่ย 61.3 ± 5.3 ปี อาสาสมัครมีฟันธรรมชาติเฉลี่ยในปากจำนวน 23 ซี่ขณะเริ่มต้นศึกษา ในการติดตามผลร้อยละ 38 ของอาสาสมัครสูญเสียฟันอย่างน้อย 1 ซี่ ในโมเดลสุดท้าย สภาวะปริทันต์ ปริมาณคราบจุลินทรีย์ การเข้ารับบริการทางทันตกรรมที่ไม่สม่ำเสมอ และรายได้น้อย ร่วมกับปัจจัยทางคลินิกคือจำนวนฟันธรรมชาติที่เหลืออยู่และจำนวนด้านรากฟันที่มีการอุด เป็นปัจจัยทำนายที่สำคัญต่ออุบัติการณ์การสูญเสียฟันในระยะเวลา 10 ปี พื้นที่ใต้เส้นโค้ง (AUC) มีค่า 0.63 บ่งชี้ระดับประสิทธิภาพในการทำนายโอกาสการสูญเสียฟันของโมเดลระดับปานกลาง

ระยะที่ 2: จากการวิเคราะห์ข้อมูลเบื้องต้นของอาสาสมัครจำนวน 900 คน เป็นเพศหญิงร้อยละ 72 อาสาสมัครมีอายุเฉลี่ย 50.36 ± 8.03 ปี โดยประมาณหนึ่งในสี่ของอาสาสมัครเป็นมุสลิม จำนวนฟันธรรมชาติเฉลี่ยจะลดลงตามกลุ่มอายุที่เพิ่มขึ้นโดยกลุ่มอายุ 35-<45, 45-<55, and ≥55 ปี จะมีจำนวนฟันธรรมชาติเฉลี่ย 27, 24, และ 20 ซี่ตามลำดับ ประมาณร้อยละ 77 ของอาสาสมัครมี

ฟันธรรมชาติเหลืออยู่ ≥ 20 ซี่ อายุที่เพิ่มขึ้น ชาวมุสลิม ระดับการศึกษาน้อย พฤติกรรมรับประทานอาหารหวานระหว่างมื้อ แปรงฟันไม่สม่ำเสมอ สภาวะโรคปริทันต์ จำนวนรากฟัน และรากฟันผุ เป็นปัจจัยทำนายที่สำคัญของการมีจำนวนฟันธรรมชาติเหลือน้อย ประมาณร้อยละ 74 เข้ารับบริการทันตกรรมในช่วงเวลา 5 ปีที่ผ่านมา โดยประมาณร้อยละ 66 ร้อยละ 21 และร้อยละ 13 มีการสูญเสียฟันจำนวน 1-2 ซี่ 3-4 ซี่ และตั้งแต่ 5 ซี่ขึ้นไปตามลำดับ ประสบการณ์การสูญเสียฟันจำนวนมาก (≥ 3 ซี่) มีความสัมพันธ์กับปัจจัยทำนายอายุที่เพิ่มขึ้น ชาวมุสลิม ระดับการศึกษาน้อย พฤติกรรมการสูบบุหรี่ แปรงฟันไม่สม่ำเสมอ โรคปริทันต์และฟันผุตัวฟัน

สรุปและข้อเสนอแนะสำหรับงานวิจัยในอนาคต: ปัจจัยทำนายที่มีความสัมพันธ์กับการมีจำนวนฟันธรรมชาติเหลือน้อยและการมีประสบการณ์สูญเสียฟันมีหลายปัจจัย โดยสภาวะปริทันต์เป็นปัจจัยทางเสี่ยงที่สำคัญต่อการสูญเสียฟันในทั้งสองกลุ่มประชากร อย่างไรก็ตามปัจจัยเกี่ยวกับฟันผุรากฟันการใช้บริการทันตกรรม การสูบบุหรี่ และปัจจัยด้านสังคมที่มีต่อการสูญเสียฟันมีความแตกต่างกันระหว่างสองกลุ่มประชากร ในการวิเคราะห์ข้อมูลและการวิจัยต่อไปในอนาคต ผู้วิจัยจะ 1) ใช้วิธีการวิเคราะห์องค์ประกอบเพื่อคัดเลือกปัจจัยทำนายที่เหมาะสม 2) ทำการทดสอบความถูกต้องและประสิทธิภาพของโมเดลประเมินความเสี่ยงต่อการสูญเสียฟัน ที่ประกอบด้วยปัจจัยทำนายต่าง ๆ ในการศึกษาระยะยาว 3) ทบทวนโมเดลความเสี่ยงและพัฒนาเครื่องให้อยู่ในเวป

คำหลัก: การสูญเสียฟัน โรคปริทันต์อักเสบ โรคฟันผุ วัยผู้ใหญ่

Introduction

Tooth loss is considered the most clinically-meaningful outcome of untreated dental caries and severe periodontal disease because it has functional and psychosocial consequences that are relevant to affected individuals. Moreover, it represents the endpoint of an accumulation of adverse social, behavioral, and biological events occurring over the course of life. Preventing tooth loss requires a long-term commitment to good oral hygiene practice. However, oral health often remains neglected, especially in older people.

The paradigm shift in oral health care from “repair model” to disease prevention and oral health promotion has been a growing concern as the financial burden of healthcare-related oral diseases is significant and major risk factors for common oral diseases (i.e. dental caries and periodontal disease) are modifiable like other non-communicable disease (NCDs). However, the change requires active patient engagement and adherence to a specific prevention and intervention plan, suggesting the need for contemporary oral health care strategy. To deliver non-paternalistic and individualized care plans, an evidence-based and patient-centered care approach is required. This project is, therefore, using multi-dimensional approach risk assessment framework to develop a risk assessment model for tooth loss in adults. The risk assessment tool facilitates the communication between health care providers and patients, encourages oral self-care in patients, and promotes public awareness of the importance of prolonging the life span of teeth.

Literature review

Oral health is an integral part of general health (1). Issues concerning recognition and acknowledgment that oral health is related to quality of life, in contrast to health related-quality of life, have been raised for over twenty years (2). The reason that the importance of oral health has been overlooked may be due to the perception that oral diseases are unimportant problems that cannot impair the quality of life. Although oral problems may not seem to be serious or life-threatening, they have significant social, economic, psychological and systemic consequences for affected individuals, especially in case of complete tooth loss (edentulism) (3-6).

Tooth loss is the ultimate outcome of two major dental problems: untreated dental caries and severe periodontal disease. Studies have shown that multiple tooth loss and complete tooth loss significantly affect oral function and diminish quality of life i.e., chewing, appearance, nutritional status, and interpersonal relationships (7, 8), and have been associated with increased mortality in older adults (7, 9-12). Fortunately, the prevalence of complete tooth loss and partial tooth loss in Thailand and worldwide has gradually declined over the past decades due to an improvement in prevention and control of these two major causes—dental caries and periodontal diseases. However, tooth loss among the elderly remains a major public health problem. Throughout the world, the prevalence of the elderly with no natural teeth range from 6% to more than 50% (13). A report from the 7th Thai National Oral Health Survey indicated 7.2% of older adults (60-74 years old) were edentate, while the proportion of adults who had at least 20 remaining teeth markedly decreased from 97.8% among middle-aged adults (35-44 years old) to 57.8% among older adults (14). The World Health Organization (WHO) has set a goal of having at least 20 natural teeth, an indicator of masticatory ability, at the age of 80 years. However, oral health surveillance data from several countries and a study conducted in Japan that compared rates of tooth loss and rates of improvements in dental care, preventive measures, and public health awareness oral health suggest that this goal will not be achieved in the near future (15).

It is inevitable that oral self-care functioning gradually declines when aging. However, with attention to oral health care earlier in life, seniors will have a better chance of complete or near-complete dentition. Population projections for Thailand indicate that the elderly will constitute an increasing proportion of the population as we proceed into the 21st century (16). A substantial number of older adults will be able to function quite independently in their communities. Others, in contrast to these community-dwelling elders, will be homebound or live in long-term care (LTC) facilities. Some may also have health

problems that increase risk of tooth loss. Maintaining masticatory ability, functional tooth units, and good oral hygiene throughout their lives is, therefore, challenging for health care providers and policy makers.

A wide variety of dental and non-dental factors related to tooth loss have been reported: clinical dental status, oral pathogenic-organisms, self-rated oral health, gender, marital status, socioeconomic status (SES), as well as physical and mental health (17-24). In addition to indicator of oral disease, a 7-year retrospective study in geriatric patients reported that the rate of tooth loss was associated with the anticholinergic drug taken, transferability, and residential status (25). However, there are few risk prediction models available to target interventions among high-risk individuals. In addition, most models have been developed to predict progression of periodontal disease or the consequence of periodontal therapy, in which tooth loss in an indicator of periodontal disease progression and failed periodontal maintenance programs. Key parameters comprise age, smoking, diabetes diagnoses, history of periodontal surgery, pocket depth, bleeding on probing, restorations with subgingingival margin, calculus, radiographic bone height, furcation involvement, and vertical bone lesions (26-27). Although biological laboratory testing is not needed, this assessment tool requires dentist and patient time, effort and a meticulous dental examination. A previous study also reported that adults with regular dental visits were found to have more retained teeth (28). In Thailand, although there is a universal coverage policy of health services, oral disease burden and low dental utilization remain the two most important oral health policy concerns (14).

With respect to the paradigmatic shift towards oral disease prevention and oral health promotion, there is a need for a contemporary oral healthcare strategy. The two primary reasons for the change are the significant financial burden of healthcare-related oral diseases and the fact that major risk factors for tooth loss are modifiable likes other non-communicable disease (NCDs). Barnfather et al. (2005) highlighted the effectiveness of immediate, individualized biofeedback to patients in a primary dental care setting to stimulate behavior changes to improve oral health (29). However, to move from traditional dental treatment (repair-based approach) to oral disease prevention and oral health promotion, a strong commitment from health care providers to involvement in the practice of preventive health as well as active patient engagement and adherence to a directed prevention and intervention plan is required. Importantly, it is essential to have a validating tool that helps health care providers educate their patients, identify an appropriate preventive approach, and monitor the change.

In dentistry, several risk assessment models and guidelines are available for periodontal disease, caries, and oral cancer in both paper-based and computer-based forms. However, most are disease-specific risk assessment tools (24, 25, 30, 31). As mentioned earlier, the primary causes of tooth loss in adults (i.e., untreated dental caries and severe periodontal diseases) shared several risk factors, which are modifiable. Thus, a combination and an integration of validated risk factors into one system will result in more cost effective measures (32, 33). This study intends to develop a risk assessment model for tooth loss in Thai middle-aged adults and the elderly under a multi-dimensional risk assessment framework.

Compared to one that is paper-based, a computer-based risk assessment can provide oral health information as well as a risk-based preventive plan remotely to people via online interaction. In addition, technology can provide tools to promote oral health literacy and to reach groups which may not otherwise be easily targeted, such as working people, homebound people, or those who are functionally limited. For future study, we aim to 1) test the longitudinal validity and accuracy of the proposed paper-based risk; and 2) transfer the revised tool to a computer-based system.

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Objectives and methods

Objectives

The purpose of this study is to develop a risk assessment model for tooth loss in using multi-dimensional risk assessment framework.

Research plan

Study design is summarized in Figure 1.

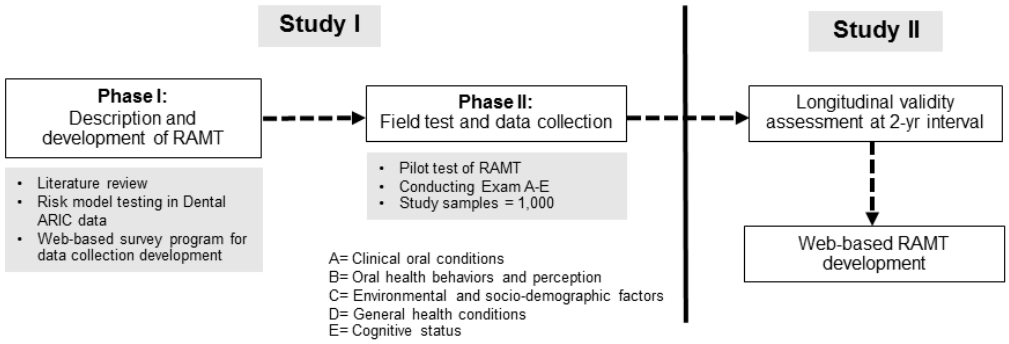

Figure 1: Study design and data collection

Phase I: Description and development of risk assessment model for tooth loss

Data set and participants

For this phase, initial sets of risk factors, risk indicators, and protective factors for predicting future tooth loss will be drafted based on Thai National Oral Health Survey reports, the literature reviews, and previous oral diseases risk assessment models. Additionally, we will use the Dental Atherosclerosis Risk in Communities (ARIC) study dataset to explore potential factors in the following categories: 1) clinical oral health conditions, 2) oral health behaviors and perception, 3) social and environmental factors, 4) general health conditions.

In brief, the Dental ARIC study is an ancillary study of ARIC, a prospective investigation of the etiology and natural history of atherosclerosis and clinical cardiovascular disease in four U.S. communities (Forsyth county, NC; Washington County, MD; suburban Minneapolis, MN; and Jackson, MS). In the period 1996-1998, comprehensive dental examinations, which included periodontal probing; collection of gingival crevicular fluid (GCF), dental plaque, and serum; and interview were carried out. In 2012-2013, participants were contacted and asked at the follow-up visit to assess tooth loss in the past ten years. The answers were categorized as “none”, “one or two”, “three or more” and “don’t know”.

Dental examination and interview at Visit 4

During the dental examination, the numbers of teeth present, root fragments, decayed surfaces, and filled surfaces were recorded. Individuals received periodontal probing depth (PPD) and gingival recession (GR) assessments at six sites per tooth on all teeth with a UNC-15 periodontal probe by trained examiners. The clinical attachment level (CAL) was calculated from the sum of PPD and GR scores. After each quadrant of probing depth measures was completed, bleeding on probing (BOP) was assessed as either present or absent for each site in that quadrant. Plaque deposit on the buccal surface of each tooth was recorded as absent or deposits covering <1/3, < 2/3, and >2/3 of the surface. The extent of BOP and plaque deposits was derived from the percentage of sites or surfaces with the presence of bleeding or visible plaque deposits. Periodontal disease prevalence at baseline was derived according to CDC/AAP periodontal disease case classification. Moderate periodontitis was defined as ≥ 2 interproximal sites with CAL ≥ 4 mm (not on the same tooth) or ≥ 2 interproximal sites with PPD ≥ 5 mm (not on the same tooth). Severe periodontitis was defined as ≥ 2 interproximal sites with CAL ≥ 6 mm (not on the same tooth) and ≥ 1 interproximal site with PPD ≥ 5 mm (not on the same tooth).

The following variables were also considered as potential predictors in the analysis: a) oral health behaviors (tooth brushing, dental flossing, last dental visit, and reason to visit a dentist), b) medical history and health behaviors (hypertension, diabetes, smoking and alcohol use), and c) socio-demographic factors (age, race, gender, education, and income). The information was obtained from answers to a self-reported questionnaire. Frequency of tooth brushing was categorized as *not at all*, *one time*, or *two or more times in the preceding day*. Frequency of dental flossing was categorized as *not at all*, *one time*, or *two or more times in the preceding week*. Time since last dental visit was categorized as < *12 months*, *12-36 months*, or > *36 months*. Reasons for dental visits were categorized as *on a regular basis*, *when there is a problem*, and *do not see a dentist*. Hypertension was defined as a previous diagnosis of hypertension, taking hypertension medication, or having a current systolic blood pressure of 140 mm Hg or higher or a diastolic blood pressure or 90 mm Hg. Diabetic status was determined by fasting plasma glucose ≥ 126 mg/dL, non-fasting plasma glucose ≥ 200 mg/dL, self-reported history of physician-diagnosed diabetes, or current medication for diabetes. Smoking and alcohol use were coded as *current*, *former*, and *never*. Race was classified as African-American or white. Participants' education was grouped as basic (< 12 years), intermediate (12-16 years), or advanced (≥ 17 years). Income was coded as < $25,000, $25,000-$50,000, >$50,000, or not reported.

At Visit 4, of the 11,337 participants completing a dental screening questionnaire, approximately 14% (n = 1,590) reported complete tooth loss. Among 9,726 dentate participants, 68.6% (n = 6,676) received comprehensive dental examinations.

Telephone interview at 2012-2013 follow-up

Participants were asked at the follow-up call to assess tooth loss in the previous ten years: "Have you lost any teeth in the past ten years?" The answers were categorized as *none*, *one or two*, *three or more*, and *don't know*. For the purpose of this analysis, eligible subjects were dentate people who received dental examinations at Visit 4, and participated in semi-annual follow-up interviews in 2012-2013. Of 6,676 dentate participants, there were 4,034 study subjects (60.4%) eligible for the analysis.

In this study, we did not validate participants' responses to the question. Therefore, we excluded from the analyses participants (n = 40) who responded to the question with *don't know*.

Statistical analysis

All analyses were performed using SAS 9.3 (Cary, NC, USA) and STATA version 13 (Texas, USA). We primarily used a complete case analysis for the outcome variable and assessed the frequency and pattern of missing independent variables. After excluding those with missing covariates (n = 472), the final analytic samples included 3,522 subjects. The outcome measure will be self-reported tooth loss in the 10 years preceding the 2012-2013 semi-annual telephone interview. For the purposes of this study, the primary outcome was self-reported tooth loss dichotomized as loss of at least one tooth or none. Number of remaining teeth was also grouped as ≥*20 teeth*, *10-19 teeth*, and *1-9 teeth*. Predictor variables from ARIC Visit 4 include socio-demographics, self-reported health status, health behavior, oral hygiene care, dental service use, and clinical dental findings (e.g., periodontal disease, number of remaining teeth, and gingival bleeding). Descriptive statistics were used to evaluate the distribution of the categorical and continuous independent variables. Bivariate analyses (Chi-square test and one-way ANOVA) were used to evaluate the associations between characteristics at the time of the dental exam with the 10-year incidence categorized as *loss of none*, *one or two*, and *three or more* teeth. Characteristics between people retained and those lost to follow-up were compared.

In further analysis, we divided potential predictors in the Dental ARIC study into four blocks as follows: a) clinical dental variables, b) oral health behaviors, c) medical history and health behaviors, and d) socio-demographic factors. To identify the best subsets of these potential predictors for each block, four multivariable models were constructed using

log-binomial regression in which the outcome is a dichotomous variable indicating whether or not at least one tooth had been lost in the previous ten years. The effect of all predictors with respect to the study outcome and adjusting for variables in each block was determined. If their *p-values* remained < 0.10 after adjustment within their own groups, they were considered for inclusion in a predictive model.

To construct a clinical dental model that would be useful to predict tooth loss incidence, clinical dental indicators and oral health behaviors, considered as etiologic factors and suspected etiologic factors, were entered into the initial model. Variables that had *p-value* > 0.10 were then eliminated. For individual predictors, one group was nominated as a reference category. Relative risks (RR) for other categories were calculated, along with their corresponding 95% confidence interval (CI). Sensitivity (Se), specificity (Sp), and positive predictive values (PPV) of the initial clinical model. The threshold for the predicted probability was set at the observed incidence of self-reported tooth loss, which was 0.386. Subsequently, to improve predictability, variables indicating medical history, health behaviors, and socio-demographic factors were added to the initial model. We then compared Se, Sp, and PPV with the initial model to determine if predictive accuracy had been improved. Model fit was assessed using area under the receiver operating characteristic (AUC) curve.

Phase II: Field test and data collection

Data set and participants

The present study was a cross-section study, conducted in four study sites: Klong Hoi Kong, Songkla; La-ngu, Satul; Nayong, Trang; and Papayom, Patthalung. Prince of Songkla University institutional review board approved the research protocol (IRB # EC5801-01-L-LR). Eligible study participants were Thai male or female age aged 35-65 years old who were living in the study areas and not moving within 2 years. They were firstly contacted by village health volunteers. Individuals who were interested to participate in the study were asked to come to hospital or sub-district health promoting hospital in their study area.

Dental examination and interview

The fieldwork team included an examiner (dentist), a data recorder, and three interviewers. Practical and theoretical training was performed around 1-2 weeks before data collection. After obtaining informed consent from the study participants, interview and dental examination were carried out. Interview questions included socio-demographic characteristics (e.g. age, race, gender, education, and income); oral health behaviors (e.g.

tooth brushing, denture cleaning, last dental visit, and having desert between meals), medical history and health behaviors (e.g. hypertension, diabetes, smoking and alcohol use), self-reported oral health problems in the past 6 months; dental service uses as well as tooth loss in the past 5 years, and oral health related quality of life. Cognitive function was assessed using MOCA Montreal for adults aged 45 years and older. The answers to a self-reported questionnaire were recorded using web-based survey program developed for this study.

Age was grouped as 35-<45; 45-<55, ≥55 years old. Religion was classified as Muslim or Buddhism. Participants' education was grouped as basic (≤ 6 years), intermediate (7-≤12 years), or advanced (>12 years). Frequency of tooth brushing was categorized as *not at all* or *one time, two times*, and *two or more times in the preceding day*. Frequency of having desert between meals was categorized as *not at all*, *1-2 days, 3-4 days, and* ≥ 5 days *in the preceding week*. Time since last dental visit was categorized as *<5 years* and *never or more than 5 years.* For those who reported last dental visit less than 5 years, they were asked about type of dental service used and number of extracted teeth. Hypertension was defined as a previous diagnosis of hypertension and taking hypertension medication. Diabetic status was determined self-reported history of physician-diagnosed diabetes, or current medication for diabetes. Smoking and alcohol use were coded as *current*, *former*, and *never*.

During the dental examination, the numbers of teeth present, root fragments, decayed teeth, and filled teeth were recorded. Individuals received periodontal probing depth (PPD) assessment at two sites (mesio-buccal and disto-buccal) per tooth on all teeth except third molars and retained roots with a WHO periodontal probe by a dentist. The greater number of probing depth was recorded as the representative probing depth of that tooth. In this study community periodontal index (CPI) was used for periodontal assessment. Percent of teeth with probing depth 6 mm, 4-5-mm, and <4 mm were then calculated.

Statistical methods

The data analyses were completed using STATA version 13 (Texas, USA. Descriptive statistics were used to evaluate the distribution of the categorical and continuous independent variables. Various testing procedures, including Chi-square tests, one-way ANOVA, and Fisher exact tests were used to examine univariate associations of baseline characteristics with number of remaining teeth and self-reported tooth loss in the past 5 years.

We primarily used a complete case analysis for two outcome variables (i.e. number of remaining teeth and self-reported tooth in the past 5 years. The final analytic samples included 900 and 669 subjects, respectively. Number of remaining teeth was also grouped as *≥20 teeth*, *10-19 teeth*, and *1-9 teeth*. Number of extracted teeth or tooth loss was classified as *none, 1-2 teeth*, and *≥3 teeth*. Predictor variables from ARIC Visit 4 include socio-demographics, self-reported health status, health behavior, oral hygiene care, dental service use, and clinical dental findings (e.g., periodontal disease, number of remaining teeth, and gingival bleeding).

We divided potential predictors into three blocks as follows: a) socio-demographic factors; b) medical history and health behaviors; c) clinical dental variables. Four multivariable models were constructed using ordered logistic regression in which the outcome was a categorical variable. The effect of each predictor with respect to the study outcome adjusting for other variables was calculated as proportional odds and its corresponding 95% confidence intervals.

Results: Phase I

Characteristics of study participants

Of the 3,522 study subjects with complete data, 85.3 % were white and 60.0 % were female, with an average age of 61.3 ± 5.3 years at Visit 4. Compared to study participants with complete data, those lost to follow-up or with missing data were on average older, more likely male and more likely African-American. They also were more likely to have less education, lower income, more medical conditions, and poor oral health (data not shown in Table).

Among subjects with complete data, the prevalence of untreated coronal caries, root caries, and severe periodontitis was approximately 15.2%, 5.4%, and 14.9%, respectively. Subjects had an average of 22.8 ± 6.6 remaining natural teeth with an average of 0.04 ± 0.3 root fragments, 0.4 ± 1.4 decayed and 18.2 ± 12.7 filled coronal surfaces, and 0.1 ± 0.6 decayed and 0.7 ± 1.5 filled root surfaces (data not shown in Table).

10-year incident tooth loss and related factors

Over one-third (38.6%) of study participants reported loss of at least one tooth during the 10-year period. In the bivariate analyses, tooth loss incidence did not differ significantly across age groups, while race, study center, gender, educational attainment, income, smoking, alcohol use, diabetes mellitus, and hypertension were significantly associated with the self-reported tooth loss (Table 1). About 44% of African-Americans lost at least one tooth versus 37.8 % of white subjects. In addition, tooth loss ≥ 3 was found to be more than twice as high among African-Americans compared to white participants (26.5% vs. 12.4%). Males were more likely to have lost more teeth (≥ 3 teeth) than females (17.7% vs. 12.2%). About half of participants with basic education lost at least one tooth during the follow-up, while about one third of participants with advanced education experienced tooth loss. Compared to participants with high income, those with low income were more likely to have experienced a greater amount of tooth loss. In addition, participants who lost many teeth tended to report that they were current smokers, former drinkers, or were diagnosed as having diabetes or hypertension at baseline (Table 1).

In bivariate analyses, baseline clinical measures of oral health and oral health behaviors differed significantly according to levels of incident tooth loss. Individuals who had lost 3 teeth or more had fewer teeth at baseline on average than those who had lost none, although individuals who had lost 1-2 teeth had more (Table 2). In addition, 33%, 43%, and 38% of subjects with 1-9, 10-19, and ≥ 20 remaining teeth respectively had lost at least one tooth. Tooth loss incidence was associated with greater numbers of retained root, root

caries, coronal caries, and filled root surfaces at baseline. They also tended to have a greater extent of gingival bleeding and visible plaque deposit. More than half of participants with severe periodontitis (55.8%) had lost at least one tooth compared to one third (31.2%) of participants with none or mild periodontitis (Table 2).

Tooth loss incidence was associated with all four oral health behaviors: infrequent tooth brushing, infrequent tooth flossing, longer period since the last dental visit, and infrequent or symptomatic dental visits (Table 3).

Predictors of a 10-year tooth loss incidence

Findings from multivariable analysis within each block of variables are presented in Table 4. In the first block, numbers of teeth, number of filled root surfaces, extent of gingival bleeding and plaque deposits, and periodontal disease showed significant associations with the outcome (*p-value* < 0.10). In the second block, positive associations of dental flossing, reasons to visit a dentist, and tooth loss (*p-value* < 0.10) were observed. In the third block, smoking and alcohol use were associated with tooth loss (*p-value* <0.05). In the fourth block, gender, educational level, and income were associated with tooth loss outcome (*p-value* < 0.10). Though smoking, gender, and race were not significantly associated with the outcome after adjusting for other variables, they were maintained in the final fully adjusted model because of associations found in previous studies.

Performances of four developed models were compared (Table 5). The performance of models was assessed in terms of Se (the percentage of subjects predicted to have tooth loss among the subjects who reported tooth loss events) and Sp (the percentage of subjects predicted to have no tooth loss among the subjects who reported no tooth loss events). Our analysis showed no significant difference in the “Se + Sp” among models. The performance of all prediction models achieved the Se and Sp in the range of 0.54-0.56 and 0.63-0.64. Regarding the PPV (the probability that subjects predicted to have tooth loss truly had tooth loss), all four models achieved PPV in the range of 0.48-0.50.

The final fully adjusted model included the following variables: number of teeth present, number of filled root surfaces, extent of plaque deposits, periodontal disease, reasons to visit a dentist, smoking, income, gender, and race. Compared to participants with no/mild periodontitis, those with severe periodontal disease were 1.61 times and those with moderate severe periodontitis were 1.29 times more likely to lose at least one tooth during the following period. Compared to participants with 1-9 teeth present, those with 10-19 teeth and ≥ 20 teeth were 1.35 and 1.46 times more likely to lose at least one tooth. Other predictors were weakly associated with self-reported tooth loss (Table 6).

Table 1: Ten-year incidence of self-reported tooth loss in relation to baseline characteristics (n = 3,522)

Baseline characteristics (n, row %)	10-year self-reported tooth loss			*P-value*
	None	1-2 teeth	≥3 teeth	
Total	2161 (61.4)	847 (24.0)	514 (14.6)	
Race				
African-American	291 (56.1)	85 (16.4)	143 (27.5)	<0.0001
White	1870 (62.3)	762 (25.4)	371 (12.4)	
Study centers				
Forsyth, NC	587 (64.6)	195 (21.5)	126 (13.9)	<0.0001
Jackson, MS	267 (56.6)	80 (16.9)	125 (25.5)	
Minneapolis, MN	826 (64.4)	335 (26.1)	121 (9.5)	
Washington, MD	481 (55.9)	237 (27.6)	142 (16.5)	
Age at baseline (years)				
51-59	921 (61.3)	353 (23.6)	227 (15.1)	0.1205
60-65	643 (64.0)	233 (23.2)	128 (12.8)	
> 65	597 (58.7)	261 (25.7)	159 (15.6)	
Gender				
Female	1276 (63.6)	485 (24.2)	245 (12.2)	<0.0001
Male	885 (58.4)	362 (23.9)	269 (17.7)	
Educational attainment				
Basic	173 (49.9)	75 (21.6)	99 (28.5)	<0.0001
Intermediate	968 (61.7)	369 (23.5)	231 (14.7)	
Advanced	1020 (63.5)	403 (25.1)	184 (11.4)	
Income (1996-1998 US dollar)				
<$25,000	378 (56.0)	146 (21.6)	151 (22.4)	<0.0001*
$25-<50,000	728 (58.5)	307 (24.7)	210 (16.9)	
$50,000 or more	1022 (66.1)	380 (24.6)	144 (9.3)	
Not reported	33 (58.9)	14 (25.0)	9 (16.1)	
Smoking				
Current	203 (54.9)	83 (22.4)	84 (22.7)	<0.0001
Former	907 (59.8)	375 (24.7)	236 (15.5)	
Never	1051 (64.3)	389 (23.8)	194 (11.9)	
Alcohol use				
Current	1262 (62.7)	504 (25.1)	246 (12.2)	<0.0001
Former	494 (57.0)	198 (22.9)	174 (20.1)	
Never	405 (62.9)	145 (22.5)	94 (14.6)	
Diabetes				
No	1925 (61.7)	765 (24.5)	430 (13.8)	0.0005
Yes	236 (58.7)	82 (20.4)	84 (20.9)	
Hypertension				

Baseline characteristics (n, row %)	10-year self-reported tooth loss			*P-value*
	None	1-2 teeth	≥3 teeth	
No	1369 (62.5)	536 (24.4)	287 (13.1)	0.0053
Yes	792 (59.5)	311 (23.4)	227 (17.1)	

* Fisher's exact test

Table 2: Ten-year incidence of self-reported tooth loss in relation to clinical oral health measures (n = 3,522)

Clinical oral health measures (mean, sd) at baseline	None (n= 2161)	1-2 teeth (n= 847)	≥ 3 teeth (n= 514)	*P*-value
No. of remaining teeth	22.9 ± 6.8	24.1 ± 5.3	20.1 ± 6.7	<0.0001
No. of remaining teeth (n, %)				
1-9 teeth	188 (67.38)	36 (12.90)	55 (19.71)	<0.0001
10-19 teeth	297 (57.23)	81 (15.61)	141 (27.17)	
≥ 20 teeth	1676 (61.53)	730 (26.80)	318 (11.67)	
No. of retained roots	0.04 ± 0.3	0.01 ± 0.1	0.1 ± 0.6	<0.0001
No. of decayed coronal surfaces	0.3 ± 1.2	0.3 ± 1.2	0.9 ± 2.6	<0.0001
No. of filled coronal surfaces	18.5 ± 12.7	20.1 ± 12.3	14.0 ± 12.4	<0.0001
No of decayed root surfaces	0.1 ± 0.5	0.1 ± 0.5	0.3 ± 1.0	<0.0001
No. of filled root surfaces	0.7 ± 1.4	0.7 ± 1.5	0.9 ± 1.9	0.0072
Extent of bleeding on probing	21.3 ± 20.5	22.0 ± 19.7	33.9 ± 27.1	<0.0001
Extent of plaque deposit	34.5 ± 35.5	35.6 ± 33.9	54.0 ± 39.1	<0.0001
Periodontal disease prevalence (n, %)				
None/mild	1103 (69.8)	330 (20.9)	148 (9.4)	<0.0001
Moderate	827 (58.3)	379 (26.7)	212 (15.0)	
Severe	231 (44.2)	138 (26.4)	154 (29.4)	

Table 3: Ten-year incidence of self-reported tooth loss in relation to baseline oral health behaviors (n = 3,522)

Oral health behaviors (n, %)	None (n= 2161)	1-2 teeth (n= 847)	≥ 3 teeth (n= 514)	*P*-value
Tooth brushing				
Not at all	21 (52.5)	2 (5.0)	17 (42.5)	<0.0001
One time	569 (58.7)	225 (23.2)	176 (18.1)	
Two times or more	1571 (62.5)	620 (24.7)	321 (12.8)	
Dental flossing				
Not at all	643 (56.6)	264 (23.2)	229 (20.2)	<0.0001
One time	193 (61.9)	75 (24.0)	44 (14.1)	
Two times or more	1325 (63.9)	508 (24.5)	241 (11.6)	
Last time visited a dentist				
> 36 months	136 (57.1)	40 (16.8)	62 (26.1)	<0.0001
12-36 months	224 (56.7)	85 (21.5)	86 (21.8)	
< 12 months	1801 (62.3)	722 (25.0)	366 (12.7)	
Reasons to visit a dentist				
Do not go to the dentist	16 (61.5)	1 (3.9)	9 (34.6)	<0.0001*
When have problems	380 (52.3)	153 (21.1)	193 (25.6)	
Regular basis	1765 (63.7)	693 (25.0)	312 (11.3)	

*Fisher's Exact Test

Table 4: Relative risk and 95% confidence interval of 10-year self-reported tooth loss according to clinical oral measures, oral health behaviors, medical conditions and health behaviors, and socio-demographic factors (n = 3,522)

	RR (95% CI)*	*P*-value
Block 1: Clinical oral measures		
No. of remaining teeth (Reference: 1-9 teeth)		
≥ 20 teeth	1.41 (1.17-1.70)	0.0005
10-19 teeth	1.35 (1.11-1.63)	
No. of retained roots (per 10 roots)	0.88 (0.33-2.30)	0.7859
No. of decayed coronal surfaces (per 10 surfaces)	1.06 (0.84-1.34)	0.6111
No. of filled coronal surfaces (per 10 surfaces)	0.98 (0.94-1.02)	0.2907
No. of decayed root surfaces (per 10 surfaces)	1.53 (0.88-2.68)	0.1726
No. of filled root surfaces (per 10 surfaces)	1.26 (0.99-1.60)	0.0777
Periodontal disease (Reference: None/Mild)		
Severe	1.63 (1.45-1.83)	<0.0001
Moderate	1.31 (1.19-1.45)	
Extent of bleeding on probing (per 10 %)	1.02 (1.00-1.04)	0.0305
Extent of plaque deposit (per 10 %)	1.02 (1.01-1.03)	0.0019
Block 2: Oral health behaviors		
Tooth brushing (Reference: ≥ 2 times/ day)		
Not at all	1.13 (0.81-1.58)	0.4697
One time	1.05 (0.96-1.15)	
Flossing (Reference: ≥ 2 times /week)		
Not at all	1.11 (1.01-1.22)	0.0897
One time	1.01 (0.87-1.18)	
Last time visited a dentist (Reference: < 12 months)		
> 36 months	0.86 (0.71-1.03)	0.2545
12-<36 months	0.96 (0.84-1.10)	
Reasons to visit a dentist (Reference: Regular basis)		
Do not go to the dentist	1.14 (0.68-1.93)	<0.0001
When have problems	1.32 (1.17-1.48)	
Block 3: Medical history and health behaviors		
Smoking (Reference: Never)		
Current	1.26 (1.11-1.44)	0.0012
Former	1.14 (1.03-1.25)	
Alcohol (Reference: Never)		
Current	0.95 (0.84-1.07)	0.0252
Former	1.09 (0.95-1.24)	
Diabetes	1.04 (0.92-1.18)	0.5459
Hypertension	1.07 (0.98-1.16)	0.1392
Block 4: Socio-demographic factors		
Age at visit 4	1.00 (0.99-1.01)	0.6842

Gender: Male		1.20 (1.10-1.30)	<0.0001
Race: African-American		1.31 (0.97-1.77)	0.1452
Education (Reference: Advanced)			
	Basic	1.24 (1.08-1.41)	0.0090
	Intermediate	1.03 (0.94-1.13)	
Income (Reference: $50,000 or more)			
	Not report	1.21 (0.88-1.66)	0.0004
	<$25,000	1.26 (1.10-1.43)	
	$25-<50,000	1.22 (1.11-1.35)	

*RR (95% CI) = Relative risk and 95% confidence interval

Table 5: Summary of findings from four log-binomial regression models for prediction of 10-year incident self-reported tooth loss

Predictor variables	*P*-value for predictor variables in multivariable log-binomial regression models			
	Model 1	Model 2	Model 3	Model 4
Block 1: Clinical oral measures				
No. of remaining teeth (Reference: 1-9 teeth)	<0.0001	<0.0001	<0.0001	<0.0001
No. of filled root surfaces	0.0625	0.0745	0.0718	0.0732
Periodontal disease (Reference: None/Mild)	<0.0001	<0.0001	<0.0001	<0.0001
Extent of bleeding on probing	0.1016			
Extent of plaque deposit	0.0188	0.0016	0.0098	0.0057
Block 2: Oral health behaviors				
Flossing (Reference: ≥ 2 times/ week)	0.3525			
Reasons to visit a dentist (Reference: Regular basis)	0.0051	0.0022	0.0171	0.0156
Block 3: Medical history and health behaviors				
Smoking (Reference: Never)		0.1987	0.1097	0.1007
Alcohol (Reference: Never)		0.1357		
Block 4: Socio-demographic factors				
Gender (Reference: Female)			0.5093	0.4903
Race (Reference: White)			0.8245	0.7952
Education (Reference: Advanced)			0.1047	
Income (Reference: $50,000 or more)			0.0032	0.0005
Summary of predictive ability* and model fit				
Sensitivity	0.55	0.54	0.56	0.56
Specificity	0.64	0.63	0.65	0.64
Sensitivity + Specificity	1.19	1.17	1.21	1.20
Positive predictive value	0.49	0.48	0.50	0.50
Area under the receiver operating characteristics	0.63	0.63	0.64	0.63

*Values for sensitivity and specificity are based on classification tables that dichotomize predicted probabilities of being a case at a cut-point of 0.386.

Table 6: Association between predictors and 10-year tooth incident tooth loss in the Dental ARIC study (n = 3,522)

Predictors		RR (95% CI)*
Periodontal disease (Reference: None/Mild)		
	Severe	1.61 (1.44-1.81)
	Moderate	1.29 (1.17-1.43)
No. of remaining teeth (Reference: 1-9 teeth)		
	≥20 teeth	1.46 (1.23-1.75)
	10-19 teeth	1.35 (1.11-1.63)
No. of filled root surfaces (per 10 surfaces)		1.26 (0.99-1.60)
Extent of plaque deposit (per 10%)		1.02 (1.01-1.03)
Reasons to visit a dentist (Reference: Regular basis)		
	Do not go to the dentist	0.88 (0.54-1.43)
	When have problems	1.16 (1.04-1.29)
African-American		1.02 (0.91-1.14)
Male		1.03 (0.94-1.13)
Income (Reference: $50,000 or more)		
	Not report	1.20 (0.88-1.64)
	<$25,000	1.24 (1.10-1.39)
	$25-<50,000	1.19 (1.08-1.31)
Smoking (Reference: Never)		
	Current	1.14 (1.01-1.30)
	Former	1.07 (0.98-1.17)

*RR (95% CI) = Relative risk and 95% confidence interval

Preliminary Results: Phase II

Characteristics of the study participants

The study participants consisted of 900 Thai adults aged between 35-65 years old from four study sites (Klong Hoi Kong, Songkla; La-ngu, Satul; Nayong, Trang; and Papayom, Patthalung) enrolled between October 2015 and March 2017. Approximately 72% and 28% of participants were female and male, respectively. The mean age of participants was 50.36 ± 8.03 years (range 35-71 years) with 31% aged 55 and older. About one fourth of study participants were Muslim. More than half of study participants (~ 55%) had education six years or less. Most of study participants (81%) had universal healthcare plan (Table 7).

Systemic health, health behaviors, and dietary habits of the study participants

Prevalence of hypertension, diabetes mellitus, cardiovascular diseases, gastroesophageal reflux disease, and arthritis were about 16.2%, 8.9%, 2.0%, 3.4%, and 1.9%. These non-communicable diseases were prevalent in adults aged 55 and older. Half of the study participants reported that they had exercised in the past week. Moreover, about 50% had health check-up in the past 12 months. Most of study participants rated their health status as “good” (50.0%) or “fair” (42.7%). About 20% were former or current smoker and 15% were former or current alcohol use (Table 8).

About 25% of the study participants reported that they had soft drinks at least once in the past week and about half (46.4%) had tea or coffee almost everyday. While about 66.3% reported not having acidic drinks in the past week, about 10% reported not having acidic food and energy drink in the past week. Almost one third of the study participants (29.7%) had desert between meals in the past week (Table 9).

Self-reported oral health status of the study participants

Majority of the study participants (82%) reported that they had calculus deposit. While, more than half of the study participants perceived that tooth hypersensitivity, tooth decay, staining deposit, and malodor were oral problems in the past 6 months. The following self-reported oral health statuses were significantly difference between age groups: worn dentition, tooth mobility, supraerupted tooth, gingival bleeding, and loose denture. These problems were more prevalent among adults aged 45 more, except for gingival bleeding that was more prevalent among younger group (35-<45 years old). About 70% and 25% of the study participant rated their global oral health status as fair/poor and good, respectively (Table 10).

Dental service use and tooth loss in the past 5 years

Of 900 participants, 669 (74.3%) had dental service use in the past 5 years. While more than 60% of the study participants reported that they received dental examination, extraction (53.8%) and scaling (44.10%) were dental treatment that frequently received. The results of univariate analysis showed type of dental services were significantly associated with age groups. Participants aged 55 and older were more likely to seek extraction and prosthesis treatment compared to the younger age groups. In contrast, the younger age groups were more likely to receive dental filling and scaling than the older group (Table 11). Among individuals who reported tooth loss in the past 5 years, 66%, 21%, and 13% lost 1-2 teeth, 3-4 teeth, and 5 or more teeth, respectively. The greater number of tooth loss was significantly associated with increased age ($p<0.001$) (Figure 2).

Severity of dental decayed experience, filled teeth, and periodontal disease

The number of decayed, filled teeth, and missing teeth reflects a person's lifetime experience of dental diseases (dental caries and periodontal disease). The average number of remaining teeth per person decreased with increased age: 27.30 ± 3.90, 24.23 ± 6.53, and 20.20 ± 8.22 per person for 35-<45, 45-<55, and ≥55 years old respectively. In contrast average number of retained roots and root decays significantly increased across age groups (Table 12). Percentage of teeth with probing depth 4-5 mm and 6 mm were also increased across age groups. Adults aged ≥55 years old had average 30% and 7% of teeth with probing depth 4-5 mm and 6 mm, respectively (Table 12 and 13).

Associations of socio-demographic factors and health behaviors with number of remaining teeth

Table 14 and 15 shows that number of remaining teeth was significantly associated with age groups, study sites, religion, educational levels, marital status, and health insurance. About 40%, 20%, and 7% of adults aged 55 and older, 45-<55, and 35-<45 had < 20 teeth, respectively. Majority of Muslim individuals in this study were from La-ngu, Satul. They were more likely to had <20 teeth compared to Buddhism (40% vs. 20%). Thirty percent of adults who had education ≤6 years had <20 teeth, while 20% and only 6% of those who had education 7-≤12 and >12 years had <20 teeth. Study participants who had less teeth were more likely to be those who had desert between meals 5 days or more in the preceding week and never or had last dental visits more than 5 years. Adults who never or tooth brushing once a day had approximately 2 times the percentage of retaining <20 teeth than those who brushed their teeth 2 times or more (38% vs 22% and 20%).

Predictors for number of remaining teeth and self-reported tooth loss in the past 5 years

Findings from multivariable analysis within each block of variables are presented in Table 16 and 17. In the first block (model 1), age, religion, and educational level were associated with both number of remaining teeth and self-reported tooth loss in the past 5 years. In the second block (model 2), positive associations of smoking and less frequent tooth brushing with self-reported tooth loss in the past 5 years were observed. While, less frequent tooth brushing and having desert between meals >3 days in the past week were associated with having fewer teeth. In the third block (model 3), number of retained roots, root decays, and percent teeth with probing depth ≥6 mm were associated with increased odds of having fewer teeth. The final fully adjusted model included the following variables: number of teeth present, number of filled root surfaces, extent of plaque deposits, periodontal disease, reasons to visit a dentist, smoking, income, gender, and race. Compared to participants with no/mild periodontitis, those with severe periodontal disease were 1.61 times and those with moderate severe periodontitis were 1.29 times more likely to lose at least one tooth during the following period. Compared to participants with 1-9 teeth present, those with 10-19 teeth and ≥ 20 teeth were 1.35 and 1.46 times more likely to lose at least one tooth. Other predictors were weakly associated with self-reported tooth loss (Table 6).

Ongoing analysis for phase II

Only preliminary results of phase II are presented in this report. Many factors are associated with risk of having fewer teeth and greater number of tooth loss in the past 5 years. Periodontal disease and tooth brushing were significant risk factors for both outcomes. This finding was in agreement with the analysis of Dental ARIC study that periodontal disease was an important predictors for 10-year self-reported tooth loss incidence in adults. However, the role of root caries, dental service use, smoking, and social inequalities in tooth loss were different from the previous analysis (phase I). Interestingly, the link between having fewer teeth and greater risk for tooth loss was strongly associated with religion. Further analysis will be done to examine the effect modification of religion as well as develop a risk model that is useful for Thai population.

Table 7: Socio-demographic characteristics stratified by age groups

Characteristics, n (row%)	Age groups (year)			Total	*P*-value
	35-<45	45-<55	≥55	n (col%)	
Number of subjects	256 (28.44)	361 (40.11)	283 (31.44)	900	
Age, years (mean ± SD)	40.61 ± 2.89	49.83 ± 2.92	59.84 ± 3.17	50.36 ± 8.03	
Study sites					
Klong Hoi Kong, Songkla	46 (28.05)	66 (40.24)	52 (31.71)	164 (18.22)	0.577
La-ngu, Satul	69 (28.63)	90 (37.34)	82 (34.02)	241 (26.78)	
Nayong, Trang	62 (24.90)	105 (42.17)	82 (32.93)	249 (27.67)	
Papayom, Patthalung	79 (32.11)	100 (40.65)	67 (27.24)	246 (27.33)	
Gender					
Male	59 (23.69)	101 (40.56)	89 (35.74)	249 (27.67)	0.092
Female	197 (30.26)	260 (39.94)	194 (29.80)	651 (72.33)	
Religion					
Buddhism	184 (27.54)	276 (41.32)	208 (31.14)	668 (74.22)	0.416
Muslim	72 (31.03)	85 (36.64)	75 (32.33)	232 (25.78)	
Education					
≤ 6 years	91 (18.27)	197 (39.56)	210 (42.17)	498 (55.33)	<0.001
7-≤12 years	95 (35.98)	117 (44.32)	52 (19.70)	264 (29.33)	
>12 years	70 (50.72)	47 (34.06)	21 (15.22	138 (15.33)	
Marital status					
Single	19 (38.00)	20 (40.00)	11 (22.00)	50 (5.56)	<0.001
Married	220 (30.01)	301 (41.06)	212 (28.92)	733 (81.44)	
Widow/Divorce	17 (14.53)	40 (34.19)	60 (51.28)	117 (13.00)	
Health insurance					
Civil servant medical	16 (16.33)	39 (39.80)	43 (43.00)	98 (10.89)	<0.001
Social security scheme	40 (52.63)	30 (39.47)	6 (7.89)	76 (8.44)	
Universal healthcare	200 (27.55)	292 (40.22)	234 (32.23)	726 (80.67)	
Living area					
Municipal	108 (29.11)	146 (39.35)	117 (31.54)	371 (41.22)	0.909
Rural	148 (27.98)	215 (40.64)	166 (31.38)	529 (58.78)	

Table 8: Systemic health and health behaviors stratified by age groups

Systemic health and health behaviors, n (col%)	Age groups (year)			Total n (col%)	*P*-value*
	35-<45	45-<55	≥55		
Number of subjects	256	361	283	900	
Having health check-up in the past 12 months	99 (38.67)	189 (52.35)	170 (60.07)	458 (50.89)	<0.001
Self-rated health status in the past 12 months					
Excellent	7 (2.75)	9 (2.49)	9 (3.18)	25 (2.78)	0.015
Good	151 (59.22)	182 (50.42)	121 (42.76)	454 (50.00)	
Fair	91 (35.69)	155 (42.94)	138 (48.76)	384 (42.71)	
Poor	6 (2.35)	14 (3.88)	15 (5.30)	35 (3.89)	
Hypertension	10 (3.91)	51 (14.13)	85 (30.04)	146 (16.22)	<0.001
Diabetes mellitus	10 (3.91)	29 (8.03)	41 (14.49)	80 (8.89)	<0.001
Cardiovascular diseases	1 (0.39)	3 (0.83)	14 (4.95)	18 (2.00)	<0.001
Gastroesophageal reflux disease	9 (3.52)	9 (2.49)	13 (4.59)	31 (3.44)	0.422
Arthritis	0	7 (1.94)	10 (3.53)	17 (1.89)	0.006
Smoking					
None	211 (82.75)	293 (81.16)	211 (74.56)	715 (79.56)	0.001
Former	9 (3.53)	16 (4.43)	35 (12.37)	60 (6.67)	
Current	34 (13.33)	51 (14.13)	37 (13.07)	122 (13.57)	
Alcohol drinking					
None	221 (86.67)	309 (85.60)	229 (80.92)	759 (84.43)	0.324
Former	14 (5.49)	20 (5.54)	26 (9.19)	60 (6.67)	
Current	19 (7.45)	31 (8.59)	28 (9.89)	78 (8.68)	
Having exercise in the past week					
None	139 (54.51)	185 (51.25)	115 (40.64)	439 (48.83)	0.002
1-2 days	41 (16.08)	60 (16.62)	51 (18.02)	152 (16.91)	
3-4 days	41 (16.08)	60 (16.62)	42 (14.84)	143 (15.91)	
5-7 days	33 (12.94)	55 (15.24)	75 (26.50)	163 (18.13)	

Missing n = 1 (0.11%) for health variables i.e. health check-up, self-rated health status, hypertension, diabetes, cardiovascular disease, gastroesophageal reflux disease, and arthritis

Missing n = 2 (0.22%) for smoking, alcohol, and having exercise in the past week

*Fisher's exact test

Table 9: Dietary habits stratified by age groups

Dietary habits, n (col%)	Age groups (year)			Total	*P*-value*
	35-<45	45-<55	≥55	n (col%)	
Number of subjects	255	361	283	899	
Having soft drinks in the past week					
None	158 (61.96)	283 (78.39)	229 (80.92)	670 (74.53)	<0.001
1-2 days	75 (29.41)	64 (17.73)	44 (15.55)	183 (20.36)	
3-4 days	14 (5.49)	7 (1.94)	8 (2.83)	29 (3.23)	
5+ days	7 (2.75)	6 (1.6)	2 (0.71)	15 (1.67)	
Having tea or coffee in the past week					
None	84 (32.94)	121 (33.52)	97 (34.28)	302 (33.59)	0.949
1-2 days	28 (10.98)	43 (11.91)	25 (8.83)	96 (10.63)	
3-4 days	25 (9.8)	31 (8.59)	26 (9.19)	82 (9.12)	
5+ days	117 (45.88)	165 (45.71)	135 (47.70)	417 (46.38)	
Having acidic drinks in the past week					
None	165 (64.17)	241 (66.76)	190 (67.14)	596 (66.30)	0.912
1-2 days	59 (23.14)	75 (20.78)	54 (19.08)	188 (20.91)	
3-4 days	15 (5.88)	26 (7.20)	23 (8.13)	64 (7.12)	
5+ days	15 (5.88)	18 (4.99)	16 (5.65)	49 (5.45)	
Having acidic food in the past week					
None	17 (6.67)	42 (11.63)	45 (15.90)	104 (11.57)	0.050
1-2 days	96 (37.65)	140 (38.78)	89 (31.45)	325 (36.15)	
3-4 days	101 (39.61)	133 (36.84)	104 (36.75)	388 (37.60)	
5+ days	40 (15.69)	45 (12.47)	45 (15.90)	130 (14.46)	
Having desert between meals in the past week					
None	74 (29.02)	82 (22.71)	78 (27.56)	234 (26.03)	0.159
1-2 days	73 (28.63)	102 (28.25)	83 (29.33)	258 (28.70)	
3-4 days	38 (14.90)	69 (19.11)	31 (10.95)	138 (15.35)	
5+ days	69 (27.06)	107 (29.64)	91 (32.16)	267 (29.70)	
Having energy drinks in the past week					
None	226 (88.63)	323 (89.47)	261 (92.23)	810 (90.10)	0.343
1-2 days	18 (7.06)	20 (5.54)	11 (3.89)	49 (5.45)	
3-4 days	3 (1.18)	11 (3.05)	8 (2.83)	22 (2.45)	
5+ days	7 (2.75)	6 (1.66)	3 (1.06)	16 (1.78)	

*Fisher's exact test

Missing n = 2 (0.22%) for dietary habit variables

Table 10: Self-reported oral health problems in the past 6 months stratified by age groups

Self-reported oral health problems, n (col%)	Age groups (year)			Total n (col%)	*P*-value
	35-<45	45-<55	≥55		
Number of subjects	256	361	283	900	
Toothache	68 (26.56)	93 (25.76)	70 (24.73)	231 (25.67)	0.888
Tooth hypersensitivity	143 (55.86)	208 (57.62)	143 (50.53)	494 (54.89)	0.205
Tooth decay	132 (51.56)	208 (57.62)	171 (60.42)	511 (56.78)	0.149
Faulty restorations	32 (12.50)	58 (16.07)	35 (12.37)	125 (13.89)	0.300
Worn dentition	92 (35.94)	159 (44.04)	135 (47.70)	386 (42.89)	0.037
Tooth mobility	34 (13.28)	113 (31.30)	113 (39.93)	260 (28.89)	<0.001
Supraerupted teeth	17 (6.64)	46 (12.74)	54 (19.08)	117 (13.00)	<0.001
Tooth migration	26 (10.16)	46 (12.74)	42 (14.48)	114 (12.67)	0.274
Gingival bleeding	103 (40.23)	118 (32.69)	75 (26.50)	296 (32.89)	0.007
Gingival swelling	72 (28.13)	101 (27.98)	75 (26.50)	248 (27.56)	0.589
Calculus deposit	215 (83.98)	299 (82.83)	227 (80.21)	741 (82.33)	0.387
Staining deposit	150 (58.59)	216 (59.83)	171 (60.42)	537 (59.67)	0.616
Oral ulcer	66 (25.78)	77 (21.33)	56 (19.79)	199 (22.11)	0.228
Malodor	137 (53.52)	204 (56.51)	154 (54.42)	465 (55.00)	0.549
Dry mouth	44 (17.19)	70 (19.39)	57 (20.14)	171 (19.00)	0.510
Fractured denture	3 (1.17)	13 (3.60)	11 (3.89)	27 (3.00)	0.157
Loose denture	4 (1.56)	20 (5.54)	22 (7.77)	46 (5.11)	0.010
Self-rated oral health					
Excellent	7 (2.73)	14 (3.88)	7 (2.47)	28 (3.11)	0.008
Good	81 (31.64)	92 (25.48)	54 (19.08)	227 (25.22)	
Fair	137 (53.52)	185 (51.25)	174 (61.48)	496 (55.11)	
Poor	30 (11.72)	70 (19.39)	48 (16.96)	148 (16.44)	

Missing n = 1 (0.11%) for the following self-reported oral health variables

Table 11: Dental service use in the past 5 years stratified by age groups

Dental service, n (col%)	Age groups (year)			Total	*P*-value
	35-<45	45-<55	≥55	n (col%)	
Number of subjects	198	263	208	669	
Dental examination	127 (64.14)	162 (61.60)	140 (67.31)	429 (64.13)	0.436
Filling	72 (36.36)	77 (29.28)	41 (19.17)	190 (28.40)	0.001
Extraction	84 (42.42)	148 (56.27)	128 (61.54)	360 (53.81)	<0.001
Surgical removal of third molars	18 (9.09)	10 (3.80)	1 (0.48)	29 (4.33)	<0.001
Scaling	102 (51.52)	119 (42.45)	74 (35.58)	295 (44.10)	0.005
Endodontic treatment	5 (2.53)	7 (2.66)	3 (1.44)	15 (2.24)	0.641
Removable prosthesis	9 (4.55)	25 (9.51)	25 (12.02)	59 (8.82)	0.026
Prosthesis repair	1 (0.51)	4 (1.52)	2 (0.96)	7 (1.05)	0.564
Crown and bridges	3 (1.52)	4 (1.52)	1 (0.48)	8 (1.20)	0.520

Of 900 participants, 669 participants received dental services in the past 5 years.

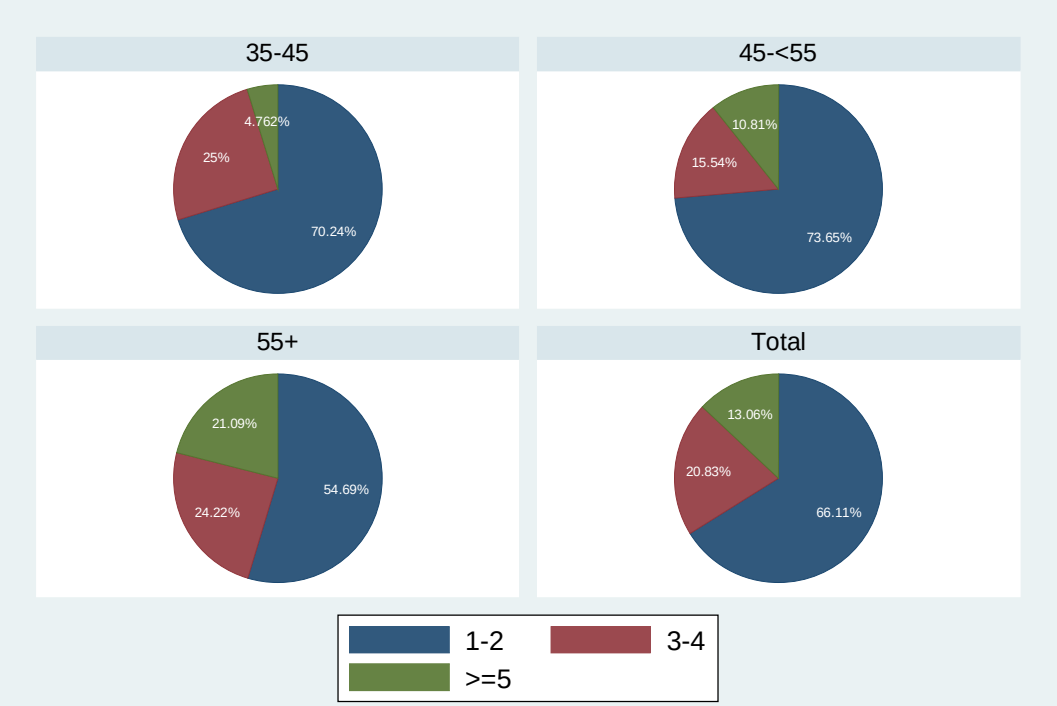

Figure 2: Self-reported number of tooth loss in the past 5 year by age groups

Table 12: Dental caries and fillings stratified by age groups

Oral health status	35-<45 years	45-<55 years	≥ 55 years	*P*-value
Number of subjects	256	361	283	
Number of remaining teeth				
Mean ± SD	27.30 ± 3.90	24.23 ± 6.53	20.20 ± 8.22	<0.001
Range (Max-Min)	13-32	1-32	0-32	
Number of retained roots				
Mean ± SD	0.60 ± 1.62	0.92 ± 2.06	1.11 ± 1.96	0.0087
Range (Max-Min)	0-11	0-17	0-13	
Number of teeth with coronal decays				
Mean ± SD	1.56 ± 1.93	1.52 ± 1.71	1.28 ± 1.54	0.1130
Range (Max-Min)	0-9	0-12	0-10	
Number of teeth with coronal fillings				
Mean ± SD	1.70 ± 2.48	1.44 ± 2.68	0.88 ± 2.14	0.0003
Range (Max-Min)	0-12	0-14	0-16	
Number of teeth with root decays				
Mean ± SD	0.22 ± 0.67	0.37 ± 1.00	0.50 ± 1.05	0.0020
Range (Max-Min)	0-5	0-9	0-7	
Number of teeth with root fillings				
Mean ± SD	0.34 ± 0.96	0.33 ± 1.11	0.33 ± 1.28	0.9906
Range (Max-Min)	0-5	0-9	0-9	

Table 13: Periodontal health status by age groups

Periodontal health status	35-<45 years	45-<55 years	≥ 55 years	*P*-value
Number of subjects	256	361	283	
Percent teeth with gingival bleeding				
Mean ± SD	28.42 ± 30.39	19.70 ± 27.43	16.27 ± 27.46	<0.001
Range (Max-Min)	0-100	0-100	0-100	
Percent teeth with calculus and gingival bleeding				
Mean ± SD	40.96 ± 28.00	41.59 ± 27.79	40.72 ± 30.61	0.9249
Range (Max-Min)	0-100	0-100	0-100	
Percent teeth with probing depth 4-5 mm				
Mean ± SD	22.56 ± 22.26	29.68 ± 25.36	34.05 ± 29.32	<0.001
Range (Max-Min)	0-96.30	0-100	0-100	
Percent teeth with probing depth ≥ 6 mm				
Mean ± SD	2.78 ± 10.28	7.05 ± 18.81	7.48 ± 18.35	0.0004
Range (Max-Min)	0-66.67	0-100	0-100	
Number of teeth with 3 degree mobility				
Mean ± SD	0.20 ± 1.31	0.60 ± 1.54	0.81 ± 1.75	<0.001
Range (Max-Min)	0-17	0-13	0-10	

Table 14: Associations between socio-demographic factors and number of remaining teeth

Characteristics, n (row%)	Number of remaining teeth			
	≥20 teeth	10-19 teeth	1-9 teeth	*P*-value
Number of subjects	695	149	56	
Age groups (years)				
35-<45	239 (93.36)	17 (6.64)	0	<0.001
45-<55	287 (79.50)	57 (15.79)	17 (4.71)	
≥ 55	169 (59.72)	75 (26.50)	39 (13.78)	
Study sites				
Klong Hoi Kong, Songkla	131 (79.88)	25 (15.24)	8 (4.88)	<0.001
La-ngu, Satul	143 (59.34)	71 (29.46)	27 (11.20)	
Nayong, Trang	199 (79.92)	32 (12.85)	18 (7.23)	
Papayom, Patthalung	222 (90.24)	21 (8.54)	3 (1.22)	
Gender				
Female	503 (77.27)	113 (17.36)	35 (5.38)	0.164
Male	192 (77.11)	36 (14.46)	21 (8.43)	
Religion				
Buddhism	558 (83.53)	80 (11.98)	30 (4.49)	<0.001
Muslim	137 (59.05)	69 (29.74)	26 (11.21)	
Education				
≤ 6 years	350 (70.28)	104 (20.88)	44 (8.84)	<0.001
7-≤12 years	215 (81.44)	38 (14.39)	11 (4.17)	
>12 years	130 (94.20)	7 (5.07)	1 (0.72)	
Marital status				
Single	44 (88.00)	6 (12.00)	0	0.018
Married	559 (77.63)	122 (16.64)	42 (5.73)	
Widow/Divorce	82 (70.09)	21 (17.95)	14 (11.97)	
Health insurance				
Civil servant medical	77 (78.57)	14 (14.29)	7 (7.14)	0.001
Social security scheme	73 (96.05)	1 (1.32)	2 (2.63)	
Universal healthcare	545 (75.07)	134 (18.46)	47 (6.47)	
Living area				
Municipal	295 (79.51)	58 (15.63)	18 (4.85)	0.265
Rural	400 (75.61)	91 (17.20)	38 (7.18)	

Table 15: Associations of health and oral health behaviors with number of remaining teeth

Heath and oral health behaviors, n (row%)	Number of remaining teeth			*P*-value
	≥ 20 teeth	10-19 teeth	1-9 teeth	
Number of subjects	695	149	56	
Smoking				
None	557 (77.90)	123 (17.20)	35 (4.90)	0.013
Former	43 (71.67)	7 (11.67)	10 (16.67)	
Current	92 (75.41)	19 (15.57)	11 (9.02)	
Alcohol drinking				
None	582 (59.53)	134 (17.65)	43 (5.67)	0.010
Former	40 (66.67)	12 (20.00)	8 (13.33)	
Current	70 (89.74)	3 (3.85)	5 (6.41)	
Having desert between meals in the past week				
None	196 (83.76)	23 (9.83)	15 (6.41)	<0.001
1-2 days	211 (81.78)	34 (13.18)	13 (5.04)	
3-4 days	119 (86.23)	16 (11.59)	3 (2.17)	
5+ days	166 (62.17)	76 (28.46)	25 (9.36)	
Diabetes mellitus				
Yes	54 (67.50)	17 (21.25)	9 (11.25)	0.193
No	640 (78.14)	132 (16.12)	47 (5.74)	
Last dental service use				
Less than 5 years	521 (77.88)	115 (17.19)	33 (4.93)	0.021
Never or more than 5 years	174 (75.32)	34 (14.72)	23 (9.96)	
Tooth brushing per day				
>2 times	152 (80.42)	26 (13.76)	11 (5.82)	0.001
2 times	467 (78.02)	107 (16.80)	33 (5.18)	
1 or none	46 (62.16)	16 (21.62)	12 (16.22)	

Table 16: Proportional odds and 95% confidence intervals for number of remaining teeth

	Proportional odd ratio and 95% CI			
Predictors	Model 1	Model 2	Model 3	Model 4
Age groups (years)				
≥ 55	9.48 (5.32-16.89)			9.33 (5.02-17.34)
45-<55	3.72 (2.09-6.61)			3.33 (1.80-6.14)
35-<45	Reference			Reference
Muslim	4.08 (2.86-5.81)			3.64 (2.37-5.60)
Buddhism	Reference			Reference
Education				
>12 years	0.21 (0.10-0.46)			0.33 (0.15-0.74)
7-≤12 years	0.77 (0.52-1.14)			0.93 (0.61-1.41)
≤ 6 years	Reference			Reference
Smoking				
Former/Current		1.31 (0.81-2.11)		0.90 (0.52-1.55)
None		Reference		Reference
Alcohol drinking				
Former/Current		0.68 (0.39-1.19)		0.80 (0.42-1.52)
None		Reference		Reference
Having desert between meals in the past week				
3-4 days/5+ days		1.96 (1.42-2.70)		1.11 (0.74-1.65)
None/1-2 days		Reference		Reference
Last dental service use				
Never or more than 5 years		1.21 (0.84-1.74)		0.92 (0.60-1.39)
Less than 5 years		Reference		Reference
Tooth brushing per day				
1 or none		2.78 (1.49-5.18)		1.92 (0.92-4.01)
2 times		1.21 (0.80-1.82)		1.59 (0.98-2.60)
>2 times		Reference		Reference
Percent teeth with probing depth ≥ 6 mm			1.02 (1.01-1.03)	1.02 (1.01-1.03)
Number of teeth with coronal decays			0.96 (0.87-1.06)	1.03 (0.95-1.15)
Number of teeth with root decays			1.38 (1.27-1.49)	1.33 (1.22-1.44)
Number of retained roots			1.41 (1.18-1.66)	1.26 (1.06-1.50)

Proportional odds and 95% confidence intervals estimated the odds of having number of remaining teeth: ≥ 1-9 teeth vs. 10-19 teeth or ≥ 20 teeth; and ≥ 1-9 teeth and 10-19 teeth vs. ≥ 20 teeth

Table 17: Proportional odds and 95% confidence intervals for self-reported tooth loss in the past 5 years

	Proportional odd ratio and 95% CI			
Predictors	Model 1	Model 2	Model 3	Model 4
Age groups (years)				
≥ 55	1.93 (1.29-2.87)			1.95 (1.28-2.96)
45-<55	1.42 (0.99-2.05)			1.38 (0.95-2.01)
35-<45	Reference			Reference
Muslim	1.61 (1.17-2.24)			1.60 (1.10-2.32)
Buddhism	Reference			Reference
Education				
>12 years	0.35 (0.22-0.55)			0.41 (0.26-0.66)
7-≤12 years	0.73 (0.53-1.02)			0.75 (0.53-1.05)
≤ 6 years	Reference			Reference
Smoking				
Former/Current		2.50 (1.55-4.04)		2.05 (1.24-3.38)
None		Reference		Reference
Alcohol drinking				
Former/Current		0.59 (0.35-1.00)		0.65 (0.38-1.12)
None		Reference		Reference
Having desert between meals in the past week				
3-4 days/5+ days		1.30 (0.97-1.74)		1.15 (0.84-1.57)
None/1-2 days		Reference		Reference
Tooth brushing per day				
1 or none		2.54 (1.28-5.04)		1.89 (0.92-3.89)
2 times		1.78 (1.23-2.57)		1.76 (1.19-2.60)
>2 times		Reference		Reference
Percent teeth with probing depth ≥ 6 mm			1.01 (1.00-1.02)	1.02 (1.01-1.03)
Number of teeth with coronal decays			1.13 (1.04-1.22)	1.17 (1.07-1.28)
Number of teeth with root decays			0.91 (0.84-0.99)	0.94 (0.85-1.04)
Number of retained roots			1.14 (0.98-1.33)	1.02 (0.85-1.22)

Proportional odds and 95% confidence intervals estimated the odds of self-reported tooth loss in the past 5 years: ≥ 3 teeth vs. 1-2 teeth or none; and ≥ 3 teeth and 1-2 teeth vs. none

Discussion and Conclusion: Phase I

More than one third of study participants experienced tooth loss within a 10-year period. In the multivariable model, periodontitis was the strongest predictor among oral disease indicators measured; however, infrequent/symptomatic dental visits and low socio-economic status (though not race and gender) were significant non-clinical predictors.

The most important strengths of the present study are the use of data from the large population-based cohort of community-dwelling, late middle-aged adults in the U.S. and the comprehensive oral examination data. Aside from providing information about etiologic mechanisms in tooth loss, the analyses identify the types of the Dental ARIC participants who are most likely to experience tooth loss. Also, this is the first study of tooth loss incidence to use the CDC/AAP classification of periodontitis as a predictor of tooth loss. A number of potential limitations of this study should be acknowledged. First, the study participants were healthier than the non-participants at baseline dental examination. These differences raised concern about selection bias. Second, the reliability of interview data was not assessed. However, many studies (1, 2) have found high agreement between the clinically recorded and the self-reported number of teeth. Consequently, it is unlikely that the self-reported tooth loss has biased the results.

Several epidemiologic studies have reported tooth loss incidence in the elderly, each with different periods of follow-up and outcome measures (3-6). The study in elderly Iowans that had a similar follow-up period reported that maximum periodontal attachment loss per person was the only predictor significantly associated with the occurrence of tooth loss after adjusting for other baseline characteristics. That study reported a higher incidence (~62%) of tooth loss than the present study (~39%). Such result may be due to participants who were generally older at baseline ($\geq$ 65 years) (7).

A high burden of periodontal disease in the U.S. has been previously reported (22). Severe periodontitis prevalence (CDC/AAP case definition) estimated in 2009-2012 surveys in the U.S. was 8.9%, representing approximately 5.8 million people (8). In our study, severe periodontitis prevalence at baseline (1996-1998) was 14.9% and more than half of the participants with severe periodontitis (55.8%) reported tooth loss at least once in the previous ten years. As study participants were from only four study sites, we acknowledge that the results of this study cannot be generalized to the U.S. population. Nonetheless, these findings demonstrate there is a need for effective periodontal disease prevention as the accumulative loss of teeth over a lifetime may affect the well-being of older adults (9, 10-12).

In the present study, the incidence of tooth loss was greater in low socio-economic groups as defined by income and education. This finding is in agreement with previous studies that highlighted low income as a predisposing factor for tooth loss and complete tooth loss (13-15). Drake et.al, (1995) reported that predictors for tooth loss among whites differed from blacks in the Piedmont 65+ Dental study. In that study, untreated caries were a major cause of tooth loss in both racial groups, while periodontal disease was a risk predictor only for blacks (5). In this multivariable analysis, however, we did not observe significant associations between untreated caries with tooth loss outcome as differing by race. Gender and race were significantly associated with tooth loss outcome in bivariate analyses, but did not play a significant role in predicting future tooth loss in multivariable analyses. This may be because the numbers of remaining teeth at baseline were similar for both gender groups (22.5 ± 6.6 for women, and 23.1 ± 6.5 for men). African-American participants were more likely to have low income, less schooling, less use of dental services (data not shown), and a higher tooth loss incidence than their white counterparts, as shown in the bivariate analyses. When controlling for gender and income, race was not independently associated with tooth loss outcome. These results indicated that the association between race and tooth loss was mediated by socio-economic status. Current smokers were also at greater risk of losing teeth in the bivariate analyses, an outcome which is in agreement with results from previous investigations (3, 4). However, in the final model, the effect of cigarette smoking on tooth loss is non-significant. This may be because smoking is a major risk factor for periodontal disease; thus, smoking became less significant in multivariable models (4).

Periodontal disease, number of remaining teeth, filled root surfaces and extent of plaque deposits were significant clinical predictors in multivariable models. Surprisingly, people with a greater number of teeth present at baseline were at a higher risk of experiencing tooth loss incidence. There are two possible explanations for this phenomenon. First, persons who presented with a greater number of remaining teeth did not necessarily have better teeth conditions. At baseline, they may have had several periodontally compromised teeth or teeth conditions that were subjected to dental diseases. For example, about 60% of people who have at least 10 teeth compared to 45% of those with fewer teeth (<10 teeth) were diagnosed with moderate or severe periodontitis (data not shown in Table). Second, tooth loss in older adults is related to social and behavioral factors as well as mental and physical health (4, 7, 15-17). Perhaps, factors such as declining ability to maintain proper oral care, less frequent dental care due to financial

limitations (13), and physical mobility (18) have greater effects on older adults with a greater amount of natural dentition, an increasing risk of dental disease, and tooth loss.

The prediction models for 10-year tooth loss incidence reported in this article were based on a combination of risk predictors and yielded 0.62-0.63 overall predictive power. According to the thresholds for interpretation of AUC proposed by Swets, AUC < 0.70 is considered as “poor” (19). To identify meaningful variables for tooth loss prediction, we used a hierarchical approach for model building. In model 1, all predictors (a combination between clinical parameters and oral health behavior factors) except dental flossing were statistically associated with tooth loss events and provided the model’s predictive power of 0.63. Even when adding other variables (medical history and socio-demographics) into the initial model, little or no improvement for the predictive ability was observed though these factors were associated with poor oral health conditions in the cross-sectional analysis (20). There are three possible explanations. First, tooth loss is a result of many factors and their interactions involving clinical conditions, clinicians’ judgments, insurance coverage, patients’ medical health, and patients’ behaviors (4, 7, 15-17), as discussed previously. It is worth noting that this study did not differentiate tooth loss by cause. In addition, it is impossible to assess all possible elements of this study. Factors such as physical disabilities, drug-related anticholinergic burdens, and cognitive impairment have been reported in previous studies as factors associated with tooth loss in older adults (18, 21). In this study, however, we did not include these parameters in the model.

Second, the contribution of periodontal disease to tooth loss may depend on the exposure definitions of periodontitis. Case definitions for periodontal diseases are crucial as they affect the internal and external validity of the study, estimation of periodontal treatment needs as well as comparisons among the epidemiologic studies (22). A study that compared several definitions of periodontal disease for predicting 5-year tooth loss events suggested that prediction models need to be gender and age specific and mean CAL was the best definition to assess incident tooth loss. For subjects aged 60-81 years, predictive values for 5-year tooth loss models yielded 0.82-0.86, which achieved “useful” levels of prediction for tooth loss. However, the tooth loss and periodontal assessment in that study were restricted to half-mouth examinations (23).

Lastly, it is unlikely that any causal prediction model will have a much higher discriminatory accuracy, given the low relative risks associated with available potential predictors identified from previously published articles and multivariable regression models (4, 5, 7, 16-17, 21, 24). Several factors, e.g., tooth brushing and diabetes, were not included

in the final model because of their weak effects or lack of statistical significance. Those factors will have to be reconsidered once additional evidence becomes available concerning their significant effects on risk for tooth loss. As the current model is not perfect, adding new predictors or changing the parameters that have reasonable cost, acceptability, and strong association with tooth loss are necessary to arrive at useful model parameters (25).

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Output

1. ผลงานตีพิมพ์ในวารสารวิชาการนานาชาติ (ระบุชื่อผู้แต่ง ชื่อเรื่อง ชื่อวารสาร ปี เล่มที่ เลขที่ และหน้า) หรือผลงานตามที่คาดไว้ในสัญญาโครงการ

Naorungroj S, Slade GD, Divaris K, et.al. Racial differences in periodontal disease and 10-year self-reported tooth loss among late middle-aged and older adults: The Dental ARIC Study. J Public Health Dent 2017; Jun 6. doi: 0.1111/jphd.12226. [Epub ahead of print] PMID: 28585323

2. การนำผลงานวิจัยไปใช้ประโยชน์

งานวิจัยนี้ได้นำไปใช้ประโยชน์ในเชิงวิชาการ เนื่องมีผลงานตีพิมพ์จากโครงการวิจัยในวารสารระดับนานาชาติ ข้อมูลจากการวิจัยได้นำไปใช้เป็นประโยชน์ในการเรียน การสอน แก่นักศึกษาและทันตแพทย์ ในเรื่องปัจจัยเสี่ยงต่อการสูญเสียฟันและปัญหาสุขภาพช่องปากของผู้สูงอายุ ในด้านชุมชนและพื้นที่ ข้อมูลจากการทำวิจัยจะถูกนำไปเสนอต่อบุคลากรในพื้นที่ศึกษา เพื่อนำไปสู่การดำเนินโครงการส่งเสริม ป้องกันการสูญเสียฟันในผู้ใหญ่ที่มีปัจจัยเสี่ยงต่าง ๆ กันลำดับต่อไป นอกจากนี้จะเป็นข้อมูลพื้นฐานสำหรับการวิจัยต่อยอดถึงการหามาตรการ กลยุทธ์ที่เหมาะสมและมีประสิทธิภาพในการลดความเสี่ยงต่อการสูญเสียฟันในผู้ใหญ่

3. อื่นๆ (เช่น ผลงานตีพิมพ์ในวารสารวิชาการในประเทศ การเสนอผลงานในที่ประชุมวิชาการ หนังสือ การจดสิทธิบัตร)

การนำเสนอผลงานในที่ประชุมวิชาการแบบ poster 2 ครั้ง

AADR/IADR 94th IADR/APR Annual Meeting, Seoul, Korea (Jun 22-25, 2016)

Tooth loss and oral health-related quality of life in a group of Thai Muslims

16th TRF-OHEC Annual Congress, Petchburi, Thailand (Jan 11-13, 2017)

Predictors of 10-year-self-reported tooth loss in the Dental ARIC study

Appendix

Poster presentation

Meeting: AADR/IADR 94th IADR/APR Annual Meeting, Seoul, Korea (Jun 22-25, 2016)

PSU Prince of Songkla University

Tooth Loss and Oral Health-related Quality of Life in a Group of Thai Muslims

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Introduction: Tooth loss is a risk indicator for chronic systemic conditions[1,2], and the negative impacts on oral health-related quality of life (OHRQoL) is particularly significant among adults with extensive tooth loss[3,4]. In Thailand, Islam is the second most populous religion and the majority of them resides in the Southern region. However, less is known on dental status and perception regarding the important of oral health and its impacts in this population.
Objective: To assess the prevalence of tooth loss, self-reported oral problems, oral health-related quality of life, and their associations in adult Thai Muslims.

Methods: ***Study samples and setting:*** This study is a cross-sectional analysis of baseline data of a 2-year longitudinal study of tooth loss incidence. Data were collected in September and December 2015 in Paknam and Kampang Sub-Districts, La-Ngu District, Satun Province, Thailand. ***Interviews:*** The face-to-face interview collected data on socio-demographic variables, oral and health behaviors, medical history, self-rated overall oral health, oral health problems in the past 12 months, and the Oral Impacts on Daily Performance (OIDP) questionnaire. ***Clinical oral examination:*** All clinical oral examination was conducted by one examiner, involving the assessment of the number of tooth present, coronal and root caries, tooth mobility, and periodontal status. The number of teeth retained, excluding retained roots, was grouped as 1-19 and ≥ 20 teeth. ***Statistical methods:*** The associations of the number of teeth present with study subjects' characteristics and self-reported oral problems were assessed using Chi-square test. Multivariable logistic regression models for the association of the number of remaining teeth and self-reported oral problems with oral impacts, adjusting for age, gender, and education were carried out (STATA version17).

Results: The analytic sample included 222 dentate subjects aged 35-65.

Table 1: Associations between study characteristics and the number of teeth present

Characteristics	≥20 teeth (n, %) n = 130	1-19 teeth (n, %) n = 92	P-value
Age (years)			
35-44	61 (91.04)	6 (8.96)	**<0.001**
45-54	45 (55.56)	36 (44.44)	
55-65	24 (32.43)	50 (67.57)	
Gender			
Female	83 (58.04)	60 (41.96)	0.833
Male	47 (59.49)	32 (40.51)	
Educational levels			
≤6 years	57 (45.97)	67 (54.03)	**<0.001**
>6 years	73 (74.49)	25 (25.51)	
Health insurance			
Universal healthcare	99 (54.70)	82 (45.30)	**0.014**
Others*	31 (75.61)	10 (24.39)	
Smoking			
Current or Former	37 (57.81)	27 (42.19)	0.886
Never	93 (58.86)	65 (41.14)	
Alcohol drinking			
Current or Former	14 (56.00)	11 (44.00)	0.873
Never	116 (58.88)	81 (41.12)	
Hypertension			
Yes	16 (53.33)	14 (46.67)	0.532
No	114 (59.38)	78 (40.63)	
Diabetes			
Yes	7 (41.18)	10 (58.82)	0.130
No	123 (60.00)	82 (40.00)	

*Civil servant medical benefit scheme and Social security scheme

Table 2: Associations between self-reported oral problems and the number of teeth present

Self-reported items	≥20 teeth (n, col%) n = 130	1-19 teeth (n, col%) n = 92	P-value
Toothache	34 (26.15)	25 (27.17)	0.865
Hypersensitivity	81 (62.31)	45 (48.91)	**0.047**
Tooth decay	62 (47.69)	66 (71.74)	**<0.001**
Faulty restorations	17 (13.08)	4 (4.35)	**0.029**
Worn dentition	73 (56.15)	51 (55.43)	0.915
Tooth mobility	30 (23.08)	53 (56.52)	**<0.001**
Gingival bleeding	47 (36.15)	28 (30.43)	0.375
Gingival swelling	44 (33.85)	26 (28.26)	0.378
Calculus deposit	104 (80.00)	69 (75.00)	0.376
Malodor	90 (69.23)	64 (69.57)	0.958
Dry mouth	32 (24.62)	22 (23.91)	0.904
Overall oral health			
Excellent or good	41(31.54)	18 (19.57)	**0.002**
Fair	75 (57.69)	48 (52.17)	
Poor	14 (10.77)	26 (28.26)	

Conclusion: Tooth loss, oral health problems, and their impacts affecting daily life performance were common among adult Thai Muslims. Those with fewer teeth had significantly impaired OHRQoL.

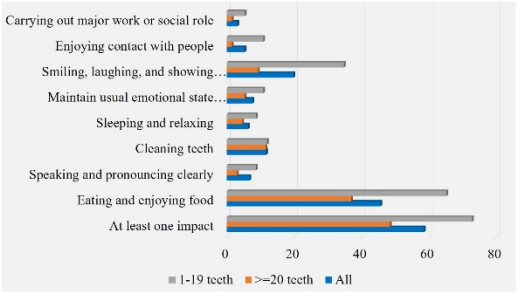

Figure 1: Prevalence of overall impacts and each item with respect to the number of teeth present

Table 3: Adjusted OR and 95% CI for the associations between the number of teeth present and self-reported oral problems with oral impacts

Characteristics	No impact (n, row%) n = 92	≥ 1 Impacts (n, row%) n = 130	Adjusted OR (95% CI)*
1-19 vs. ≥20 teeth	25 (27.17)	67 (72.83)	**2.98 (1.53-5.78)**
Self-reported oral problems (Ref = no)			
Toothache	15 (25.42)	44 (74.58)	**2.78 (1.41-5.50)**
Hypersensitivity	47 (37.30)	79 (62.70)	1.60 (0.91-2.81)
Tooth decay	45 (35.16)	83 (64.84)	**1.94 (1.10-3.40)**
Faulty restorations	6 (28.57)	15 (71.43)	2.18 (0.79-5.97)
Worn dentition	45 (36.29)	79 (63.71)	**1.79 (1.01-3.17)**
Tooth mobility	26 (31.71)	56 (68.29)	**1.92 (1.05-3.51)**
Gingival bleeding	30 (40.00)	45 (60.00)	1.13 (0.63-2.04)
Gingival swelling	24 (34.29)	46 (65.71)	1.54 (0.84-2.81)
Calculus deposit	65 (37.57)	108 (62.43)	**2.42 (1.21-4.82)**
Malodor	59 (38.31)	95 (61.69)	**1.93 (1.03-3.60)**
Dry mouth	20 (37.04)	34 (62.96)	1.36 (0.71-2.61)
Overall oral health (Ref = excellent or good)			
Poor	9 (22.50)	31 (77.50)	**7.56 (2.95-19.35)**
Fair	42 (34.15)	81 (65.85)	**4.39 (2.23-8.64)**

*Adjusting for age, gender, and education

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Predictors of 10-year-self-reported tooth loss in the Dental ARIC study

PJ-BIOL-04

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The Thailand Research Fund

Introduction: Tooth loss is the most clinically meaningful outcome of untreated dental caries and severe periodontal disease. It represents the endpoint of an accumulation of adverse social, behavioral, and biological events occurring over the life course[1].Tooth loss has been associated with diminished quality of life and is a risk indicator for chronic systemic conditions and even mortality in older adults[2-4]. Predictors for tooth loss include both proximal causes, such as caries and periodontitis, and broader risk indicators, such as self-rated oral health, physical and mental health, and socioeconomic status (SES). Most of these factors were statistically significant but made small contributions to variation in incident tooth loss[5-7].

Objective: This study investigated 10-year-self-reported tooth loss incidence and its risk indicators among participants in the Atherosclerosis Risk in Communities (ARIC) and Dental ARIC study.

Methods: ***Study samples:*** This analysis was based on existing data from ARIC and Dental ARIC studies. The ARIC study is a prospective investigation of the etiology and natural history of atherosclerosis and clinical cardiovascular disease of middle-aged adults (aged 45-64 at the inception) enrolled between 1987-1989 in four U.S. communities. Dental ARIC, an ancillary study of the ARIC, was conducted at in 1996-98. For this analysis, the eligible subjects were dentate people who received dental examinations and participated in semi-annual follow-up interviews in 2012-13. Of **6,676** dentate participants, there were **4,034** study subjects (60.4%) eligible for the analysis.

Dental examination and interviews in 1996-98: The numbers of teeth present, root fragments, decayed surfaces, and filled surfaces were recorded. Individuals received periodontal probing depth (PPD) and gingival recession (GR) assessments at six sites per tooth on all teeth. Bleeding on probing (BOP) and plaque deposit were also assessed. The following variables were obtained from answers to a self-reported questionnaire a) **oral health behaviors** (tooth brushing, dental flossing, last dental visit, and reason to visit a dentist), b) **medical history and health behaviors** (hypertension, diabetes, smoking and alcohol use), and c) **socio-demographic factors** (age, race, gender, education, and income).

Telephone interview in 2012-13 follow-up: Participants were asked at the follow-up call to assess tooth loss in the previous ten years: "Have you lost any teeth in the past ten years?" The answers were categorized as *none*, *one or two*, *three or more*, and *don't know*. In this study, we did not validate participants' responses to the question. Therefore, we excluded from the analyses participants (n = 40) who responded to the question with *don't know*.

Statistical methods: After excluding those with missing covariates (n = 472), the final analytic samples included **3,522** subjects (STATA version17). Multivariable models were constructed using log-binomial regression in which the outcome is a dichotomous variable indicating whether or not at least one tooth has ben lost in the previous ten years. Relative risks (RR) and 95% confidence interval (CI)for other categories were calculated.

Results: Of the 3,522 study subjects with complete data, 85.3 % were white and 60.0 % were female, with an average age of 61.3 ± 5.3 years at baseline. The prevalence of untreated coronal caries, root caries, and severe periodontitis was approximately 15.2%, 5.4%, and 14.9%, respectively. Subjects had an average of 22.8 ± 6.6 remaining natural teeth with an average of 0.04 ± 0.3 root fragments, 0.4 ± 1.4 decayed and 18.2 ± 12.7 filled coronal surfaces, and 0.1 ± 0.6 decayed and 0.7 ± 1.5 filled root surfaces.

Table 1: *Baseline characteristics and 10-year incidence tooth loss*

Baseline characteristics (n, row %)	10-year self-reported tooth loss			P-value
	None	1-2 teeth	≥ 3 teeth	
Total	2161 (61.4)	847 (24.0)	514 (14.6)	
African-American	291 (56.1)	85 (16.4)	143 (27.5)	<0.0001
Age at baseline (years)				
51-59	921 (61.3)	353 (23.6)	227 (15.1)	0.1205
60-65	643 (64.0)	233 (23.2)	128 (12.8)	
> 65	597 (58.7)	261 (25.7)	159 (15.6)	
Female	1276 (63.6)	485 (24.2)	245 (12.2)	<0.0001
Educational attainment				
Basic	173 (49.9)	75 (21.6)	99 (28.5)	<0.0001
Intermediate	968 (61.7)	369 (23.5)	231 (14.7)	
Advanced	1020 (63.5)	403 (25.1)	184 (11.4)	
Income				
<$25,000	378 (56.0)	146 (21.6)	151 (22.4)	<0.0001*
$25-<50,000	728 (58.5)	307 (24.7)	210 (16.9)	
$50,000 or more	1022 (66.1)	380 (24.6)	144 (9.3)	
Not reported	33 (58.9)	14 (25.0)	9 (16.1)	
Smoking				
Current	203 (54.9)	83 (22.4)	84 (22.7)	<0.0001
Former	907 (59.8)	375 (24.7)	236 (15.5)	
Never	1051 (64.3)	389 (23.8)	194 (11.9)	
Alcohol use				
Current	1262 (62.7)	504 (25.1)	246 (12.2)	<0.0001
Former	494 (57.0)	198 (22.9)	174 (20.1)	
Never	405 (62.9)	145 (22.5)	94 (14.6)	
Diabetes	236 (58.7)	82 (20.4)	84 (20.9)	0.0005
Hypertension	792 (59.5)	311 (23.4)	227 (17.1)	0.0053

*Fisher's exact test

Table 2: *Associations between predictors and 10-year incidence tooth loss*

Predictors	RR (95% CI)
Periodontal disease (Ref: None/Mild)	
Severe	1.61 (1.44-1.81)
Moderate	1.29 (1.17-1.43)
No. of remaining teeth (Ref: 1-9 teeth)	
≥20 teeth	1.46 (1.23-1.75)
10-19 teeth	1.35 (1.11-1.63)
No. of filled root surfaces (per 10 surfaces)	1.26 (0.99-1.60)
Extent of plaque deposit (per 10%)	1.02 (1.01-1.03)
Reasons to visit a dentist (Ref: Regular basis)	
Do not go to the dentist	0.88 (0.54-1.43)
When have problems	1.16 (1.04-1.29)
African-American	1.02 (0.91-1.14)
Male	1.03 (0.94-1.13)
Income (Ref: $50,000 or more)	
Not report	1.20 (0.88-1.64)
<$25,000	1.24 (1.10-1.39)
$25-<50,000	1.19 (1.08-1.31)
Smoking (Ref: Never)	
Current	1.14 (1.01-1.30)
Former	1.07 (0.98-1.17)

Conclusion: Greater severity of periodontal disease, not dental caries, is significantly associated with an increased risk for tooth loss after taking into account socio-demographic factors, oral health and health behaviors, and medical conditions.

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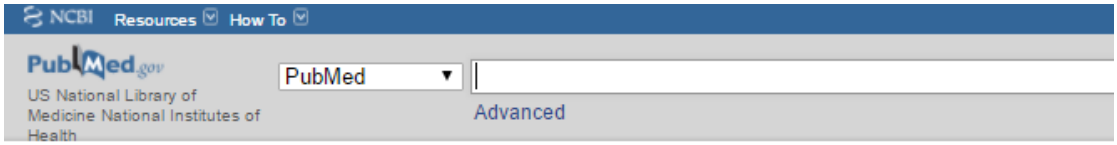

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Racial differences in periodontal disease and 10-year self-reported tooth loss among late middle-aged and older adults: the dental ARIC study.

Naorungroj S[1,2], Slade GD[3], Divaris K[4,5], Heiss G[5], Offenbacher S[6], Beck JD[3].

Author information

Abstract

OBJECTIVE: To investigate racial differences in the associations between periodontitis and 10-year self-reported incident tooth loss in a biracial, community-based cohort of US late middle-aged and older adults.

METHODS: Subjects were 3,466 dentate men and women aged 53-74 who underwent dental examinations from 1996 to1998. In 2012-2013, telephone interviewers asked participants about tooth loss in the preceding 10 years. Separate multivariable ordinal logistic regression models were used to calculate proportional odds ratios (OR) and 95% confidence intervals (CI) as estimates of association between periodontitis and tooth loss for Whites and African-Americans (AAs).

RESULTS: The majority of participants were White (85 percent) and female (57 percent) with 23 teeth on average at enrollment. Approximately half the Whites (56 percent) and AAs (49 percent) had periodontitis. At follow-up, approximately 44 percent of AAs and 38 percent of Whites reported having lost ≥1 tooth. In multivariable models, severe periodontitis (OR = 3.03; 95% CI = 2.42-3.80) and moderate periodontitis (OR = 1.64; 95% CI= 1.39-1.94) were significant risk factors of incident tooth loss among Whites. For AAs, severe but not moderate periodontitis increased the odds of incident tooth loss (OR = 2.22; 95% CI = 1.37-3.59). In the final model, education was inversely associated with incident tooth loss among AAs, while lower income was associated with greater odds of tooth loss among Whites.

CONCLUSIONS: In this population-based cohort, there is racial heterogeneity in the association between periodontitis and tooth loss. Interventions to reduce the impact of periodontitis on tooth loss need to consider these differences.

KEYWORDS: cohort study; periodontitis; race; socioeconomic status; tooth loss

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Racial differences in periodontal disease and 10-year self-reported tooth loss among late middle-aged and older adults: the dental ARIC study

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Keywords
tooth loss; periodontitis; cohort study; race; socioeconomic status.

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Conclusions: In this population-based cohort, there is racial heterogeneity in the association between periodontitis and tooth loss. Interventions to reduce the impact of periodontitis on tooth loss need to consider these differences.

Introduction

Tooth loss has been associated with diminished quality of life and is a risk indicator for chronic systemic conditions such as cardiovascular disease, diabetes, and even mortality in older adults (1-3). While the prevalence of complete tooth loss (edentulism) in the United States has decreased in successive generations born after the middle of the 20th century, complete tooth loss affected 24 percent of Americans aged 65–74 years in 1999–2004. However, the trend of the decline of edentulism and number of missing teeth varied across race and socioeconomic (SES) groups (4). Improving oral health in the elderly has been highly emphasized. *Healthy People 2020* includes a goal to reduce complete tooth loss by 10 percent (to 21.6 percent) among this age group (5). However, there are few models available to target interventions among individuals at high-risk for tooth loss (6-10).

Predictors for tooth loss identified in previous studies include both proximal causes, such as oral pathogenic micro-organisms, dental caries and periodontitis, and broader risk indicators, such as self-rated oral health, oral pathogenic micro-organisms, SES, physical and mental health, demographic (2,6-8,10,11), attitudes, and behaviors (such as dental service used and reason for seeking dental treatment) (11-13). Most of these factors were statistically significant, but made small contributions to variation in incident tooth loss. Furthermore, the majority of evidence is from cross-sectional analyses (2,4,14) or prospective cohort studies with a short follow-up period (7,9,11,13,15). To systematically examine the combined influences of biological, social, and behavioral determinants on incident tooth loss, large sample sizes and extended follow-up studies are needed.

Racial disparities in dental diseases, including but not limited to tooth loss, dental caries, and periodontitis in the United States, have been acknowledged (2,4,5,16). A previous study in older adults identified that significant predictors for tooth loss for Whites were different from African-Americans (AAs). Active caries was a major cause of tooth loss for both races, whereas periodontitis was a predictor only for AAs (7). In addition, a recent study among middle-aged and older adults pointed out that racial disparities in edentulism and tooth loss were partially explained by SES and that the associations were complicated. Compared to Whites, AAs had a higher probability of edentulism; however, when the outcome was adjusted for education and income, AAs had lower odds of edentulism (4). AAs and those of low SES may experience less risk for tooth loss due to the indication that they are less likely to access dental care (11,17).

In the United States, the prevalence of untreated tooth decay is still high in late middle-aged and older adults (11 percent and 17 percent, respectively) and much higher for periodontitis for (53 percent and 68 percent, respectively) (18). SES factors associated with periodontal disease progression and tooth loss have been reported (15,17). However, there was limited evidence to suggest that the influence of periodontal disease on tooth loss in the elderly differs with regard to race and SES (i.e., education and income) (17). In addition, the classification developed by the Centers for Disease Control and Prevention (CDC) and the American Academy of Periodontology (AAP) is designed to provide as standard case definitions for population-based surveillance (18,19). Its use in predicting incident tooth loss has yet to be reported.

This study investigated whether racial differences exist in the association between periodontal disease and self-reported incident tooth loss, and explored the influence of SES on racial variations in the associations between periodontitis and tooth loss among late middle-aged and older adults in the Atherosclerosis Risk in Communities (ARIC) and Dental ARIC studies.

Methods

Design and study population

This analysis was based on existing data from ARIC and Dental ARIC studies. Sampling and data collection procedures used in ARIC and its ancillary studies have been described elsewhere (20,21). Briefly, the ARIC study is a prospective investigation of the etiology and natural history of atherosclerosis and clinical cardiovascular disease of middle-aged adults (15,792 individuals aged 45–64 at inception) enrolled between 1987 and 1989 (Visit 1) via probability sampling in a biracial cohort from four US communities (Forsyth County, NC; Washington County, MD; suburban Minneapolis, MN; and Jackson, MS) Participants from Washington County and Minneapolis were almost exclusively Whites, whereas the Jackson sample consisted solely of AAs. The Forsyth included AAs and Whites (20). The first four visits were conducted at approximately 3-year intervals; the last completed exam visits occurred during the period 2011–2013 (Visit 5). Annual follow-up of the cohort by telephone began in 1987 to maintain contact and to assess the health status of the cohort. Beginning in 2012, the cohort was contacted semi-annually. Dental ARIC, an ancillary study of the ARIC, was conducted at Visit 4 (1996–1998). Data collection included a comprehensive dental examination, the collection of gingival crevicular fluid, dental plaque, and serum, and an interview. Study participants requiring antibiotic prophylaxis for periodontal probing were excluded from the Dental ARIC study. At Visit 4, of the 11,337 participants completing a dental screening questionnaire, approximately 14 percent ($n = 1{,}590$) reported complete tooth loss. Among 9,726 dentate participants, 68.6 percent ($n = 6{,}676$) received comprehensive dental examinations.

For the purpose of this analysis, eligible subjects were dentate people who received dental examinations at Visit 4, and

participated in semi-annual follow-up interviews in 2012–2013. Of 6,676 dentate participants, there were 4,034 study subjects (60.4 percent) eligible for the analysis.

Baseline dental examination and interview in 1996–1998 (Visit 4)

At Visit 4, participants who were enrolled in the Dental ARIC study answered the structured questionnaires and underwent dental examinations. During the dental examination, the number of teeth present, root fragments, decayed surfaces, and filled surfaces were recorded for all teeth, including third molars. Coronal caries was recorded using criteria described by Radike. If less than one-fourth of the crown was retained, it was recorded as a root fragment. Root caries was recorded as present if there was a discrete, well-defined, and discolored cavitation on the root surface and the explorer entered easily. Individuals received periodontal probing depth (PPD) and gingival recession (GR) assessments at six sites per tooth on all teeth with a UNC-15 periodontal probe by four trained dental hygienists. Examiners were calibrated to a standard examiner, and percent agreement of clinical attachment level (CAL) within 1 mm between these examiners and the standard examiner ranged from 83.2 percent to 90.2 percent. Intra-class correlation coefficients ranged from 0.76 to 0.90, indicating excellent to outstanding agreement and weighted kappa statistics ranged from 0.76 to 0.86, indicating excellent agreement (21). The CAL was calculated from the sum of PPD and GR scores. Periodontal disease prevalence at baseline was derived according to CDC/AAP periodontal disease case classification (22). Moderate periodontitis was defined as $\geq$2 interproximal sites with CAL $\geq$ 4 mm (not on the same tooth) or $\geq$2 interproximal sites with PPD $\geq$ 5 mm (not on the same tooth). Severe periodontitis was defined as $\geq$2 interproximal sites with CAL $\geq$ 6 mm (not on the same tooth) and $\geq$1 interproximal site with PPD $\geq$ 5 mm (not on the same tooth).

The following variables obtained from answers to a self-reported questionnaire and dental examination were considered as potential covariates in the analysis based on the behavioral model of health services utilization proposed by Andersen (23). Predictors for tooth loss were traditionally grouped as predisposing, enabling, and need factors (11,14,23). Predisposing characteristics, for example, race, gender, education, dental attitudes, oral health behaviors, and health status, were either non-modifiable or modifiable and exist prior to disease. In this study, we defined race, gender, and education as non-modifiable social characteristics, while oral health behaviors (i.e., tooth brushing, dental flossing, a reason for dental visit), smoking, diabetes were grouped as modifiable health behaviors and health status. Race was classified as AA or White. Participants' education was grouped as less than high school ($<$ 12 years), completion of high school (12–16 years), or advanced ($\geq$ 17 years). Frequency of tooth brushing was dichotomized as not at all or one time versus two or more times in the preceding day. Frequency of dental flossing was categorized as not at all, one time, or two or more times in the preceding week. The reason for dental visits was dichotomized as on a regular basis versus problem-oriented. Diabetic status was determined by fasting plasma glucose $\geq$ 126 mg/dL, non-fasting plasma glucose $\geq$ 200 mg/dL, self-reported history of physician-diagnosed diabetes, or current medication for diabetes. Smoking was coded as current, former, and never. Enabling characteristics are factors that affect one's ability to access the health care system, such as income. In this study, annual household income was used as an indicator for financial ability to use dental care. Household income was coded as $<$ \$25,000, \$25,000-\$50,000, $>$\$50,000, or not reported. Need variables indicated dental conditions or disease levels that were regarded as proximal contributors to incident tooth loss. In this analysis, baseline dental conditions were periodontal disease, number of remaining teeth, root fragment, root caries, and coronal caries. Periodontal disease was classified as severe, moderate, and none/mild as previously described. The number of remaining teeth was grouped as $\geq$20 teeth, 10–19 teeth, and 1–9 teeth. Root fragment, coronal caries and root caries were dichotomized as present or absent.

Telephone interview at 2012–2013 semi-annual follow-up

The outcome measure was self-reported tooth loss in the 10 years preceding the 2012–2013 semi-annual telephone interview. Participants were asked at the follow-up call to assess tooth loss in the previous 10 years: "Have you lost any teeth in the past ten years?" The answers were categorized as none, one or two, three or more, and do not know. In this study, we did not validate participants' responses to the question. Therefore, we excluded from the analyses participants ($n = 40$) who responded to the question with do not know.

Statistical methods

All analyses were performed using SAS 9.3 (Cary, NC, USA) and STATA 13.0 (Stata Corp., College Station, TX, USA). We primarily used a complete case analysis for the outcome variable and assessed the frequency and pattern of missing independent variables. For the purpose of the analysis, after excluding those with missing covariates and those who did not report household income ($n = 748$), the final analytic samples included 3,466 subjects. Descriptive statistics were used to evaluate the distribution of the categorical and continuous independent variables. Bivariate analyses (Chi-square test and one-way ANOVA) were used to evaluate the race-specific baseline characteristics and the associations of covariate variables at the time of the dental exam with the 10-year

Table 1 Baseline Characteristics of the Dental ARIC Follow-Up Cohort, Overall and Stratified by Race

Baseline characteristics (*n*, col%)	All (*n* = 3,466)	Whites (*n* = 2,959)	African-Americans (*n* = 507)	*P*-value
Male	1,496 (43.2)	1,318 (44.5)	178 (35.1)	<0.001
Age at baseline (years)				
51–59	1,481 (42.7)	1,191 (40.3)	290 (57.2)	<0.001
60–65	990 (28.6)	871 (29.4)	119 (23.5)	
>65	995 (28.7)	897 (30.3)	98 (19.3)	
Educational attainment				
Less than high school	342 (9.9)	229 (7.7)	113 (22.3)	<0.001
Completion of high school	1,542 (44.5)	1,386 (46.9)	156 (30.8)	
Postsecondary education	1,582 (45.6)	1,344 (45.4)	238 (46.9)	
Household income (1996–1998 US dollars)				
<$25,000	675 (19.5)	437 (14.8)	238 (47.0)	<0.001
$25-<50,000	1,245 (35.9)	1,104 (37.3)	141 (27.8)	
$50,000 or more	1,546 (44.6)	1,418 (47.9)	128 (25.2)	
Smoking				
Current	364 (10.5)	301 (10.2)	63 (12.4)	0.001
Former	1,500 (43.3)	1,318 (44.5)	182 (35.9)	
Never	1,602 (46.2)	1,340 (45.3)	262 (51.7)	
Diabetes	402 (11.6)	311 (10.5)	91 (18.0)	<0.001
Dental flossing				
Not at all	1,123 (32.4)	876 (29.6)	247 (48.7)	<0.001
One time per week	304 (8.8)	257 (8.7)	47 (9.3)	
Two times per week or more	2,039 (58.8)	1,826 (61.7)	213 (42.0)	
Brushing teeth once daily or none	996 (28.7)	832 (28.1)	164 (32.3)	0.052
Problem-oriented dental visit	742 (21.4)	427 (14.4)	315 (62.1)	<0.001
Number of remaining teeth				
1–9 teeth	275 (7.9)	179 (6.1)	96 (18.9)	<0.001
10–19 teeth	509 (14.7)	350 (11.8)	159 (31.4)	
≥20 teeth	2,682 (77.4)	2,430 (82.1)	252 (49.7)	
Root fragments	89 (2.6)	48 (1.6)	41 (8.1)	<0.001
Coronal caries	523 (15.1)	294 (9.9)	229 (45.2)	<0.001
Root caries	187 (5.4)	104 (3.5)	83 (16.4)	<0.001
Periodontal disease				
None/mild	1,556 (44.9)	1,301 (44.0)	255 (50.3)	<0.001
Moderate	1,394 (40.2)	1,232 (41.6)	162 (32.0)	
Severe	516 (14.9)	426 (14.4)	90 (17.7)	

incidence categorized as loss of none, one or two, and three or more teeth within race strata. Characteristics between people retained and those lost to follow-up were compared.

The model building strategy included a literature review and the Andersen behavioral model (7,11,13,23). Those variables that were available in the Dental ARIC dataset together with the results from bivariate analyses of covariates for incident tooth loss were considered in the multivariable analysis. We used a multivariable ordinal logistic regression model to investigate the association between periodontal disease and three categories of self-reported incident tooth loss. Parameter estimates were converted to odds ratios with 95% confidence intervals (CI). For each racial group, crude associations of periodontal disease and each covariate with self-reported tooth loss outcome were estimated. To justify the use of separate models for Whites and AAs, we evaluated a combined-race model that tested the main effect of periodontal disease, covariates, and the interaction of each covariate with race, controlling for other variables. A criterion of *P*-value <0.20 was used to determine effect heterogeneity by race. Interaction terms of eight variables with race (periodontal disease, number of remaining teeth, root fragments, coronal caries, root caries, education, diabetes, and flossing) were statistically significant. We, therefore, developed separate final models to investigate the associations of periodontal disease with the risk of losing teeth for Whites and AAs. We began with a full model controlling for baseline clinical conditions, financial ability to use dental care as indicated by household income variable, non-modifiable social characteristics and modifiable health behaviors and health status. To derive parsimonious final models, we used a backward stepwise variable selection method. A criterion of *P*-value >0.10 was used for a variable to be removed and *P*-value <0.05 for a variable to be entered in the model.

Results

The characteristics of the study samples are presented in Table 1. Of the 3,466 study subjects with complete data, 85 percent were Whites and 57 percent were female, with an average age of 61.3 ± 5.3 years at Visit 4. Compared to study participants with complete data, those lost to follow-up or with missing data were on average older, more likely male and more likely AAs. They also were more likely to have less education, lower household income, more medical conditions, and poor oral health (Supporting Information Table S1).

Table 1 presents overall all and race-specific baseline characteristics. AAs were slightly younger than Whites at baseline. Overall, a higher proportion of AAs had attained less than a high school education, low household income, diabetes, a lower frequency of self-reported tooth brushing and flossing, and irregular use of dental services, compared to Whites. Current and past smokers accounted for 54 percent of all subjects, with a greater percentage of Whites than AAs. Subjects had an average of 22.8 ± 6.6 remaining natural teeth with an average of 0.04 ± 0.3 root fragments, 0.4 ± 1.4 decayed and 18.2 ± 12.7 filled coronal surfaces, and 0.1 ± 0.6 decayed and 0.7 ± 1.5 filled root surfaces (data not shown in Table 1). Racial differences were significant for all baseline dental conditions: number of teeth, root fragment, coronal caries, root caries, and periodontal disease. Greater than 80 percent of Whites had retained ≥20 teeth, while only half of AAs had retained ≥20 teeth. The overall prevalence of root fragments, untreated coronal caries, root caries, and severe periodontitis was approximately 3 percent, 15 percent, 5 percent, and 15 percent, respectively, with a higher prevalence among AAs compared to Whites. In contrast, Whites had a greater proportion of filled coronal and root surfaces than AAs (data not shown in Table 1).

Table 2 presents the results of baseline characteristics and self-reported incident tooth loss stratified by race. Over one-third (39 percent) of study participants reported the loss of at least one tooth during the 10-year period. Approximately 44 percent of AAs lost at least one tooth versus 38 percent of white subjects. In addition, tooth loss ≥3 was found to be more than twice as high among AAs compared to white participants (27 percent versus 12 percent).

Tooth loss incidence was not significantly different between age groups for both races, while some factors, for example, gender, diabetes, and smoking, were significantly associated with self-reported tooth loss only among Whites. White men were more likely to report greater tooth loss (≥3 teeth) than white women (16 percent versus 10 percent), whereas tooth loss among AAs was similar for both men and women (30 percent versus 26 percent). Tooth loss of 1–2 teeth was slightly different for both diabetic and non-diabetic participants among AAs (18 percent versus 16 percent) and Whites (21 percent versus 26 percent), while tooth loss of more than 3 teeth was more frequently reported by AA than white participants with diabetes (36 percent versus 16 percent). Both AA and Whites who lost many teeth tended to report that they were current smokers. However, greater tooth loss (≥3) was similar for former and nonsmoking participants among AAs (27 percent versus 24 percent, respectively). Among nonsmoking participants, greater tooth loss was also more frequently reported by AAs than Whites (24 percent versus 9 percent).

For both races, tooth loss was significantly different between educational levels and income. About half of participants with basic education lost at least one tooth during the follow-up, while about one-third of participants with advanced education experienced tooth loss for both AAs and Whites. Compared to participants with high income, those with low income were more likely to have experienced more tooth loss. However, AAs tended to report loss of more teeth (≥3 teeth) than Whites across household income groups.

In bivariate analyses, oral health behaviors and baseline clinical measures of oral health differed significantly according to levels of incident tooth loss in both racial groups. Tooth loss was associated with infrequent tooth brushing, infrequent tooth flossing, and infrequent or symptomatic dental visits for both racial groups. However, AAs with infrequent tooth brushing or flossing were more likely to report loss ≥3 teeth compared to Whites (35 percent, 36 percent versus 16 percent, 16 percent, respectively).

For both AAs and Whites, individuals who lost ≥3 teeth were more likely to have had fewer teeth at baseline. In addition, while 27 percent, 41 percent, and 37 percent of white subjects with 1–9, 10–19, and ≥ 20 remaining teeth, respectively, had lost at least one tooth, almost half of AAs had lost at least one tooth across the category of remaining teeth. Tooth loss incidence was associated with greater numbers of retained root, root caries, and coronal caries in both racial groups. White participants who had root fragments reported the loss of at least one tooth more frequently than AAs (58 percent versus 41 percent). AAs who had root caries were more likely to report loss of at least one tooth than Whites (57 percent versus 48 percent), while percentages of subjects with coronal caries who had lost at least one tooth among Whites and AAs were slightly different (46 percent versus 49 percent). More than half of AA and white participants with severe periodontitis had lost at least one tooth, whereas less than one-third (28 percent) of Whites with none or mild periodontitis compared to 39 percent of AAs had lost at least one tooth.

Findings from the race-specific unadjusted and multivariable analyses are presented in Table 3. In the final model, compared to none or mild periodontitis, Whites with severe periodontitis and moderate periodontitis had 3.03 times (OR = 3.03, 95% CI = 2.42–3.80) and 1.64 times (OR = 1.64,

Table 2 Baseline Characteristics and 10-Year Self-Reported Tooth Loss by Race

	White ($n = 2,959$)				African-American ($n = 507$)			
Baseline characteristics (n, row%)	None ($n = 1,842$)	1–2 teeth ($n = 750$)	≥3teeth ($n = 367$)	P-value	None ($n = 286$)	1–2 teeth ($n = 83$)	≥3 teeth ($n = 138$)	P-value
Gender								
Male	781 (59.3)	326 (24.7)	211 (16.0)	<0.001	95 (53.4)	29 (16.3)	54 (30.3)	0.489
Female	1,061 (64.7)	424 (25.8)	156 (9.5)		191 (58.1)	54 (16.4)	84 (25.5)	
Age at baseline (years)								
51–59	753 (63.2)	291 (24.4)	147 (12.3)	0.063	157 (54.1)	56 (19.3)	77 (26.6)	0.349
60–65	563 (64.6)	215 (24.7)	93 (10.7)		72 (60.5)	14 (11.8)	33 (27.7)	
> 65	526 (58.6)	244 (27.2)	127 (14.2)		57 (58.1)	13 (13.3)	28 (28.6)	
Educational attainment								
Less than high school	124 (54.2)	58 (25.3)	47 (20.5)	<0.001	45 (39.8)	17 (15.1)	51 (45.1)	<0.001
Completion of high school	856 (61.7)	346 (25.0)	184 (13.3)		94 (60.3)	18 (11.5)	44 (28.2)	
Postsecondary education	862 (64.2)	346 (25.7)	136 (10.1)		147 (61.8)	48 (20.2)	43 (18.0)	
Household income (1996–1998 US dollars)								
<$25,000	255 (58.3)	113 (25.9)	69 (15.8)	<0.001	123 (51.7)	33 (13.9)	82 (34.4)	0.001
$25-<50,000	642 (58.1)	288 (26.1)	174 (15.8)		86 (61.0)	19 (13.5)	36 (25.5)	
$50,000 or more	945 (66.7)	349 (24.6)	124 (8.7)		77 (60.2)	31 (24.2)	20 (15.6)	
Smoking								
Current	164 (54.5)	79 (26.2)	58 (19.3)	<0.001	34 (54.0)	4 (6.3)	25 (39.7)	0.054
Former	797 (60.4)	337 (25.6)	184 (14.0)		99 (54.4)	34 (18.7)	49 (26.9)	
Never	881 (65.8)	334 (24.9)	125 (9.3)		153 (58.4)	45 (17.2)	64 (24.4)	
Diabetes								
No	1,648 (62.3)	684 (25.8)	316 (11.9)	0.033	244 (58.7)	67 (16.1)	105 (25.2)	0.064
Yes	194 (62.4)	66 (21.2)	51 (16.4)		42 (46.1)	16 (17.6)	33 (36.3)	
Dental flossing								
Not at all	509 (58.1)	226 (25.8)	141 (16.1)	<0.001	127 (51.4)	34 (13.8)	86 (34.8)	0.005
One time per week	156 (60.7)	65 (25.3)	36 (14.0)		31 (66.0)	8 (17.0)	8 (17.0)	
Two times per week or more	1,177 (64.5)	459 (25.1)	190 (10.4)		128 (60.1)	41 (19.2)	44 (20.7)	
Tooth brushing								
Once daily or none	492 (59.1)	204 (24.9)	133 (16.0)	0.001	88 (53.6)	17 (10.4)	59 (36.0)	0.002
At least twice daily	1,350 (63.5)	543 (25.5)	234 (11.0)		198 (57.7)	66 (19.2)	79 (23.1)	
Reasons to visit a dentist								
Problem-oriented	233 (54.6)	101 (23.6)	93 (21.8)	<0.001	158 (50.2)	52 (16.5)	105 (33.3)	<0.001
Regular basis	1,609 (63.6)	649 (25.6)	274 (10.8)		128 (66.7)	31 (16.1)	33 (17.2)	
Number of remaining teeth								
1–9 teeth	130 (72.6)	25 (14.0)	24 (13.4)	<0.001	55 (57.3)	11 (14.5)	30 (31.3)	<0.001
10–19 teeth	205 (58.6)	64 (18.3)	81 (23.1)		87 (54.7)	14 (8.8)	58 (36.5)	
≥20 teeth	1,507 (62.0)	661 (27.2)	262 (10.8)		144 (57.1)	58 (23.0)	50 (19.9)	
Root fragments								
No	1,822 (62.6)	743 (25.5)	349 (11.9)	<0.001	262 (56.2)	82 (17.6)	122 (26.2)	0.022
Yes	20 (41.7)	7 (14.6)	21 (43.7)		24 (58.5)	1 (2.4)	16 (39.1)	

Table 2. Continued

Baseline characteristics (*n*, row%)	White (*n* = 2,959)				African-American (*n* = 507)			
	None (*n* = 1,842)	1–2 teeth (*n* = 750)	≥3teeth (*n* = 367)	*P*-value	None (*n* = 286)	1–2 teeth (*n* = 83)	≥3 teeth (*n* = 138)	*P*-value
Coronal caries								
No	1,683 (63.1)	681 (25.6)	301 (11.3)	<0.001	170 (61.1)	53 (19.1)	55 (19.8)	<0.001
Yes	159 (54.1)	69 (23.5)	66 (22.4)		116 (50.7)	30 (13.1)	83 (36.2)	
Root caries								
No	1,788 (62.6)	729 (25.5)	338 (11.9)	<0.001	250 (59.0)	76 (17.9)	98 (23.1)	<0.001
Yes	54 (51.9)	21 (20.2)	29 (27.9)		36 (43.4)	7 (8.4)	40 (48.2)	
Periodontal disease								
None/mild	931 (71.6)	279 (21.4)	91 (7.0)	<0.001	156 (61.2)	44 (17.2)	55 (21.6)	0.003
Moderate	722 (58.6)	345 (28.0)	165 (13.4)		90 (55.5)	28 (17.3)	44 (27.2)	
Severe	189 (44.4)	126 (29.6)	111 (26.0)		40 (44.5)	11 (12.2)	39 (43.3)	

95% CI = 1.39–1.94) the odds of tooth loss, respectively. AAs with severe periodontitis had double odds (OR = 2.22, 95% CI = 1.37–3.59) for tooth loss; however, a significant difference was not observed for those with moderate periodontitis.

In the final models, the set of significant covariates for self-reported tooth loss differed between AAs and Whites. For Whites, significant covariates for tooth loss included the number of remaining teeth, root fragments, gender, household income, smoking, and reason to visit a dentist. Covariates that were significantly associated with incident tooth loss for AAs were root caries, education, diabetes, and reason to visit a dentist. No significant association between oral health behaviors (i.e., tooth brushing and flossing) with self-reported tooth loss was observed in either race. Reason to visit a dentist was an independent predictor for tooth loss in both racial groups, even after adjustment for other predictors. In the final models, odds of tooth loss was 35 percent greater in white participants (OR = 1.35, 95% CI = 1.07–1.69) and 61 percent greater in AA participants (OR = 1.61, 95% CI = 1.10–2.38) who had irregular dental visit compared to those visited a dentist on regular basis. Low level of education exhibited a strong significant association with increased odds of tooth loss among AAs, but not among Whites in the multivariable analyses. In contrast, lower household income was associated with greater odds of tooth loss among Whites, while there was little difference across household income levels. There were no significant associations observed with the level of income among AAs in the final model.

Discussion

At baseline, dentate AAs had fewer teeth, but higher prevalence of dental diseases compared to their White counterparts. As expected, a higher proportion of AAs continued to lose more teeth than Whites. In this cohort, periodontal disease exhibited stronger association with tooth loss among Whites compared to AAs. However, the different set of significant covariates in the final multivariable adjusted models between AAs and Whites, suggested effects heterogeneity for contributing factors, including income and education, to incident tooth loss between sub-populations.

The most important strengths of the present study are the use of data from the large population-based cohort of community-dwelling, late middle-aged, and older adults in the United States. Aside from providing information about etiologic mechanisms in tooth loss, the analyses identify the types of Dental ARIC participants who are most likely to experience tooth loss. Also, based on a full-mouth examination protocol, this assessment, this is the first study of tooth loss incidence to use the CDC/AAP classification of periodontitis as a predictor of tooth loss. The contribution of periodontal disease to tooth loss may depend on the exposure definitions of periodontitis. Case definitions for periodontal

Table 3 Unadjusted and Adjusted Proportional Odds Ratios (OR) and 95% Confidence Intervals (CI)* for 10-Year Self-Reported Tooth Loss

	White ($n = 2,959$)			African-American ($n = 507$)		
Baseline characteristics	Unadjusted	Full model	Final model	Unadjusted	Full model	Final model
Periodontal disease						
Moderate versus None/Mild	1.80 (1.53–2.11)	1.63 (1.38–1.93)	1.64 (1.39–1.94)	1.28 (0.87–1.88)	1.14 (0.75–1.74)	1.21 (0.81–1.79)
Severe versus None/Mild	3.49 (2.81–4.34)	2.96 (2.35–3.72)	3.03 (2.42–3.80)	2.28 (1.43–3.64)	2.14 (1.28–3.59)	2.22 (1.37–3.59)
Number of remaining teeth						
10–19 teeth versus 1–9 teeth	2.03 (1.38–3.00)	2.27 (1.51–3.42)	2.23 (1.49–3.35)	1.18 (0.72–1.95)	1.39 (0.81–2.39)	
≥20 teeth versus 1–9 teeth	1.47 (1.05–2.06)	2.19 (1.52–3.17)	2.09 (1.46–3.01)	0.84 (0.53–1.32)	1.22 (0.72–2.08)	
Root fragments versus None	3.69 (2.09–6.53)	2.90 (1.60–5.25)	2.93 (1.63–5.26)	1.18 (0.62–2.26)	0.62 (0.30–1.29)	
Coronal caries versus None	1.63 (1.29–2.07)	1.12 (0.86–1.46)		1.76 (1.25–2.47)	1.17 (0.77–1.76)	
Root caries versus None	1.89 (1.28–2.78)	1.05 (0.69–1.59)		2.39 (1.50–3.79)	1.89 (1.12–3.19)	1.86 (1.14–3.03)
Household income (1996–1998 US dollars)						
<$25,000 versus $50,000 or more	1.50 (1.21–1.56)	1.42 (1.11–1.80)	1.50 (1.19–1.89)	1.70 (1.12–2.58)	1.06 (0.62–1.81)	
$25-<50,000 versus $50,000 or more	1.51 (1.29–1.77)	1.44 (1.22–1.70)	1.47 (1.25–1.73)	1.13 (0.71–1.81)	1.05 (0.63–1.76)	
Educational attainment						
Less than high school versus Advanced	1.66 (1.26–2.18)	1.20 (0.88–1.63)		2.82 (1.83–4.35)	2.06 (1.23–3.46)	2.15 (1.36–3.41)
Completion of high school versus Advanced	1.14 (0.98–1.33)	1.06 (0.90–1.24)		1.22 (0.82–1.83)	1.00 (0.64–1.57)	1.02 (0.67–1.54)
Smoking						
Current versus Never	1.73 (1.35–2.21)	1.37 (1.06–1.77)	1.37 (1.06–1.77)	1.48 (0.86–2.55)	1.12 (0.62–2.02)	
Former versus Never	1.30 (1.11–1.51)	1.13 (0.96–1.33)	1.13 (0.96–1.33)	1.16 (0.81–1.67)	1.14 (0.77–1.69)	
Diabetes versus None	1.07 (0.84–1.35)	0.98 (0.75–1.23)		1.67 (1.08–2.56)	1.44 (0.91–2.27)	1.51 (0.96–2.37)
Dental flossing						
Not at all versus Two times per week or more	1.36 (1.16–1.60)	1.14 (0.96–1.37)		1.60 (1.12–2.29)	0.55 (0.28–1.11)	
One time versus Two times per week or more	1.21 (0.93–1.57)	1.11 (0.85–1.46)		0.79 (0.41–1.50)	0.98 (0.63–1.51)	
Brushing teeth once daily or none versus At least twice daily	1.26 (1.07-.148)	1.04 (0.88–1.24)		1.39 (0.97–2.00)	1.06 (0.70–1.60)	
Problem-oriented versus Regular dental visit	1.62 (1.33–1.99)	1.24 (0.98–1.57)	1.35 (1.07–1.69)	2.09 (1.46–3.00)	1.66 (1.05–2.60)	1.61 (1.10–2.38)
Male versus Female	1.17 (0.92–1.50)	1.12 (0.95–1.33)	1.17 (1.00–1.37)	1.23 (0.86–1.75)	1.10 (0.71–1.70)	

*Separate multivariate ordinal logistic regression models for Whites and AAs estimated the associations between periodontal disease and the proportional odds of losing teeth. In the final model for Whites, significant covariates included in the model were the number of remaining teeth, root fragments, household income, smoking, reason to visit a dentist and gender. While, covariates that were significantly associated with incident tooth loss for AAs were root caries, education, diabetes, and reason to visit a dentist.

diseases are crucial as they affect the internal and external validity of the study, estimation of periodontal treatment needs as well as comparisons among the epidemiologic studies (19). A study that compared several definitions of periodontal disease for predicting 5-year tooth loss events suggested that prediction models need to be gender- and age-specific, while mean CAL was the best definition to assess incident tooth loss. However, tooth loss and periodontal assessment in that study were restricted to half-mouth examinations (6).

A number of potential limitations of this study should be acknowledged. First, the study participants included in the analysis were healthier and had higher SES than non-participants at baseline dental examination. Prevalence of severe periodontal disease was greater among non-participants than participants (20 percent versus 15 percent). These differences raised concerns about selection bias and thus the observed effects of periodontal disease on self-reported tooth loss may be lower than the true population parameter. Second, the reliability of interview data was not assessed. However, many studies (24,25) have found high agreement between the clinically recorded and the self-reported number of teeth. Consequently, it is unlikely that the self-reported tooth loss has biased the results. Last, the generalizability of the results only extends to the four geographic areas that were sampled.

Several epidemiologic studies have reported tooth loss incidence in the elderly, each with different periods of follow-up and outcome measures (7,9,26-28). Previous prospective studies had either smaller samples with high attrition rates at follow-up (7,13,27) or shorter follow-up periods (9,13,15,26). The study in elderly Iowans that had a similar follow-up period reported that maximum periodontal attachment loss per person was the only predictor significantly associated with the occurrence of tooth loss after adjusting for other baseline characteristics. In this study, no single dental condition emerged as a dominant risk factor for tooth loss, but severe periodontal disease was the only underlying clinical condition consistently associated with tooth loss in both racial groups. The Iowa study reported a higher incidence (~62 percent) of tooth loss than this study (~39 percent). Such a result may be due to participants who were generally older at baseline ($\geq$ 65 years) (27).

A high burden of periodontal disease in the United States has been previously reported (29). Severe periodontitis prevalence (CDC/AAP case definition) estimated in 2009–2012 surveys in the United States was 8.9 percent, representing approximately 5.8 million people (29). In our study samples, severe periodontitis prevalence at baseline (1996–1998) was greater (14.9 percent) and more than half of the participants with severe periodontitis (55.8 percent) reported tooth loss at least once in the previous 10 years. However, since the study investigated the association between periodontitis and incident tooth loss, the higher prevalence is not really a limitation. Nonetheless, these findings demonstrate there is a need for effective periodontal disease prevention as the accumulative loss of teeth over a lifetime may affect the well-being of older adults (1,3).

Drake et al. reported that predictors for tooth loss among Whites differed from AAs in the Piedmont 65+ Dental Study. In that study, untreated caries was a major cause of tooth loss in both racial groups, while periodontal disease was a risk predictor only for AAs (7). Contrary to previous findings, in this multivariable analysis, untreated coronal caries was not associated with tooth loss in either race. The associations between other baseline dental conditions, that is, number of remaining teeth, root fragments, root caries, and periodontal disease, were different by race. Interestingly, we observed a stronger association between periodontal disease and incident tooth loss among Whites than AAs. These results suggest the limits of generalization of tooth loss findings across different populations and that there may be different important predictors for tooth loss.

The possible sources of the difference in the magnitude of the association between periodontal disease and incident tooth loss by race may be due to the multifactorial etiology of tooth loss, a residual confounding from number of remaining teeth, smoking, and SES, or an unmeasured confounding in this study, for example, attitudes toward oral health care and dental service use. Tooth loss is a result of many factors and their interactions involving clinical conditions, clinicians' judgments, insurance coverage, patients' medical health, and patients' behaviors (9,12,13,27,30). Our data are consistent with previous reports. Results reported in Table 3 suggest an important role for baseline dental disease or need variables in predictive tooth loss. Our results also underscore the importance of dental attendance patterns (i.e., reason to visit a dentist) for tooth loss. Although the effect size was modest, the reason to visit a dentist was the only modifiable health behavioral factor that was significantly associated with tooth loss in both races. Individuals who were problem-oriented attenders and had negative attitudes toward dental care were more likely to receive dental extractions (13). Current smokers were also at greater risk of losing teeth in the bivariate analyses which is in agreement with results from previous investigations (9,28). However, in the final model, the effect of cigarette smoking on tooth loss is attenuated and non-significant for AAs. This may be because smoking is a major risk factor for periodontal disease; thus, smoking, like diabetes, became less significant in multivariable models (9). Also, in this study, our self-reported measure of smoking status classified as former, current, and never smokers may not adequately reflect the full extent of the influence of smoking. More detailed measures of smoking (e.g., number of cigarettes, smoking duration, and cotinine levels) might have better captured the influence of smoking on incident tooth loss.

It is worth noting that this study did not differentiate tooth loss by cause. In addition, it is impossible to assess all possible influences on tooth loss in this study. Factors such as physical disabilities, drug-related anticholinergic burdens, and cognitive impairment have been reported in previous studies as factors associated with tooth loss in older adults (8,10). These factors may play different roles contributing to varying degrees to tooth loss risk in older people. In this study, however, we did not consider these parameters.

As mentioned previously, tooth loss is a complex outcome that is influenced directly by oral diseases or indirectly by social inequalities. A previous study has illustrated the mechanism of the social disparities in tooth loss (11). Race and SES were important determinants of different dental disease levels before entering the dental care system and influenced differences in dental services received after dental visits. Specifically, AAs and low SES had more dental symptoms, but were less likely to access dental care. Once they received dental care, they had significantly higher odds of tooth loss. Another study has confirmed that dental care utilization was the only factor that consistently associated with tooth loss across racial groups (17). In this study, the incidence of tooth loss was greater in low SES groups as defined by income and education. This finding is in agreement with previous studies that highlighted low income as a contributing factor for tooth loss and complete tooth loss (4,13,15). However, our data suggest that the influences of income and education on incident tooth loss differ by race. The results of the current study are in line with a previous study that showed the disparities in dental health due to SES factors are not shared equally across racial groups. Furthermore, there was a weaker association between SES with tooth loss for AAs than Whites (17). Findings in our analyses are in partially in agreement with the previous reports. Less education was associated with higher probabilities of tooth loss among AAs versus Whites. In contrast, lower household income was associated with higher probabilities of tooth loss among Whites versus AAs. At baseline, although prevalence of moderate and severe periodontal disease was slightly different between Whites and AAs, Whites had more retained teeth than AAs, with a greater chance to be affected by periodontal problems. Moreover, white participants were more likely to visit a dentist on a regular basis (86 percent) compared to AAs (38 percent). Thus, it is possible that the greater odds for tooth loss due to periodontal disease among Whites are a result of more opportunities to access dental care, though extraction may be the treatment of choice for teeth affected by severe periodontitis. Older adults may have limited financial resources to support costly dental treatment and tooth retention. This result should be interpreted with caution as information regarding dental insurance and dental visits was unavailable. In addition, we adjusted for the number of teeth, reason to visit a dentist, household income, education, though residual confounding from these factors cannot be eliminated.

As older adults tend to retain more natural teeth, and these teeth are at increased risk for caries and periodontal disease. Identifying interventions and public health programs to assist the elderly maintain a healthy dentition is a challenging but important task. Additional longitudinal studies in diverse populations are needed to better characterize factors contributing to incident tooth loss. Furthermore, collection of dental utilization data and reason for tooth loss may also serve to more fully clarify the complex associations between periodontal disease and tooth loss as well as the mechanism of SES influence in diverse racial groups.

Conclusion

Greater severity of periodontal disease is significantly associated with an increased risk for tooth loss. However, the magnitudes of the associations were not similar for Whites and AAs. The associations of education, income, and other predictors with tooth loss vary across racial groups. Interventions and public health programs need to consider these differences when attempting to reduce burden of periodontal disease on tooth loss in later life.

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SUPPORTING INFORMATION

Additional supporting information may be available on the online version of this article

Table S1 Selected Baseline Characteristics of Dentate Subjects Who Were Included and Excluded from the Analysis

Predictors of 10-year-self-reported tooth loss in the Dental ARIC study

PJ-BIOL-04

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Introduction: Tooth loss is the most clinically meaningful outcome of untreated dental caries and severe periodontal disease. It represents the endpoint of an accumulation of adverse social, behavioral, and biological events occurring over the life course[1].Tooth loss has been associated with diminished quality of life and is a risk indicator for chronic systemic conditions and even mortality in older adults[2-4]. Predictors for tooth loss include both proximal causes, such as caries and periodontitis, and broader risk indicators, such as self-rated oral health, physical and mental health, and socioeconomic status (SES). Most of these factors were statistically significant but made small contributions to variation in incident tooth loss[5-7].

Objective: This study investigated 10-year-self-reported tooth loss incidence and its risk indicators among participants in the Atherosclerosis Risk in Communities (ARIC) and Dental ARIC study.

Methods: ***Study samples:*** This analysis was based on existing data from ARIC and Dental ARIC studies. The ARIC study is a prospective investigation of the etiology and natural history of atherosclerosis and clinical cardiovascular disease of middle-aged adults (aged 45-64 at the inception) enrolled between 1987-1989 in four U.S. communities. Dental ARIC, an ancillary study of the ARIC, was conducted at in 1996-98. For this analysis, the eligible subjects were dentate people who received dental examinations and participated in semi-annual follow-up interviews in 2012-13. Of **6,676** dentate participants, there were **4,034** study subjects (60.4%) eligible for the analysis.

Dental examination and interviews in 1996-98: The numbers of teeth present, root fragments, decayed surfaces, and filled surfaces were recorded. Individuals received periodontal probing depth (PPD) and gingival recession (GR) assessments at six sites per tooth on all teeth. Bleeding on probing (BOP) and plaque deposit were also assessed. The following variables were obtained from answers to a self-reported questionnaire a) **oral health behaviors** (tooth brushing, dental flossing, last dental visit, and reason to visit a dentist), b) **medical history and health behaviors** (hypertension, diabetes, smoking and alcohol use), and c) **socio-demographic factors** (age, race, gender, education, and income).

Telephone interview in 2012-13 follow-up: Participants were asked at the follow-up call to assess tooth loss in the previous ten years: "Have you lost any teeth in the past ten years?" The answers were categorized as *none*, *one or two*, *three or more*, and *don't know*. In this study, we did not validate participants' responses to the question. Therefore, we excluded from the analyses participants (n = 40) who responded to the question with *don't know*.

Statistical methods: After excluding those with missing covariates (n = 472), the final analytic samples included **3,522** subjects (STATA version17). Multivariable models were constructed using log-binomial regression in which the outcome is a dichotomous variable indicating whether or not at least one tooth has ben lost in the previous ten years. Relative risks (RR) and 95% confidence interval (CI)for other categories were calculated.

Results: Of the 3,522 study subjects with complete data, 85.3 % were white and 60.0 % were female, with an average age of 61.3 ± 5.3 years at baseline. The prevalence of untreated coronal caries, root caries, and severe periodontitis was approximately 15.2%, 5.4%, and 14.9%, respectively. Subjects had an average of 22.8 ± 6.6 remaining natural teeth with an average of 0.04 ± 0.3 root fragments, 0.4 ± 1.4 decayed and 18.2 ± 12.7 filled coronal surfaces, and 0.1 ± 0.6 decayed and 0.7 ± 1.5 filled root surfaces.

Table 1: *Baseline characteristics and 10-year incidence tooth loss*

Baseline characteristics (n, row %)	10-year self-reported tooth loss			P-value
	None	1-2 teeth	≥ 3 teeth	
Total	2161 (61.4)	847 (24.0)	514 (14.6)	
African-American	291 (56.1)	85 (16.4)	143 (27.5)	<0.0001
Age at baseline (years)				
51-59	921 (61.3)	353 (23.6)	227 (15.1)	0.1205
60-65	643 (64.0)	233 (23.2)	128 (12.8)	
> 65	597 (58.7)	261 (25.7)	159 (15.6)	
Female	1276 (63.6)	485 (24.2)	245 (12.2)	<0.0001
Educational attainment				
Basic	173 (49.9)	75 (21.6)	99 (28.5)	<0.0001
Intermediate	968 (61.7)	369 (23.5)	231 (14.7)	
Advanced	1020 (63.5)	403 (25.1)	184 (11.4)	
Income				
<$25,000	378 (56.0)	146 (21.6)	151 (22.4)	<0.0001*
$25-<50,000	728 (58.5)	307 (24.7)	210 (16.9)	
$50,000 or more	1022 (66.1)	380 (24.6)	144 (9.3)	
Not reported	33 (58.9)	14 (25.0)	9 (16.1)	
Smoking				
Current	203 (54.9)	83 (22.4)	84 (22.7)	<0.0001
Former	907 (59.8)	375 (24.7)	236 (15.5)	
Never	1051 (64.3)	389 (23.8)	194 (11.9)	
Alcohol use				
Current	1262 (62.7)	504 (25.1)	246 (12.2)	<0.0001
Former	494 (57.0)	198 (22.9)	174 (20.1)	
Never	405 (62.9)	145 (22.5)	94 (14.6)	
Diabetes	236 (58.7)	82 (20.4)	84 (20.9)	0.0005
Hypertension	792 (59.5)	311 (23.4)	227 (17.1)	0.0053

* *Fisher's exact test*

Table 2: *Associations between predictors and 10-year incidence tooth loss*

Predictors	RR (95% CI)
Periodontal disease (Ref: None/Mild)	
Severe	1.61 (1.44-1.81)
Moderate	1.29 (1.17-1.43)
No. of remaining teeth (Ref: 1-9 teeth)	
≥20 teeth	1.46 (1.23-1.75)
10-19 teeth	1.35 (1.11-1.63)
No. of filled root surfaces (per 10 surfaces)	1.26 (0.99-1.60)
Extent of plaque deposit (per 10%)	1.02 (1.01-1.03)
Reasons to visit a dentist (Ref: Regular basis)	
Do not go to the dentist	0.88 (0.54-1.43)
When have problems	1.16 (1.04-1.29)
African-American	1.02 (0.91-1.14)
Male	1.03 (0.94-1.13)
Income (Ref: $50,000 or more)	
Not report	1.20 (0.88-1.64)
<$25,000	1.24 (1.10-1.39)
$25-<50,000	1.19 (1.08-1.31)
Smoking (Ref: Never)	
Current	1.14 (1.01-1.30)
Former	1.07 (0.98-1.17)

Conclusion: Greater severity of periodontal disease, not dental caries, is significantly associated with an increased risk for tooth loss after taking into account socio-demographic factors, oral health and health behaviors, and medical conditions.

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