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## Risk indicators for the presence and extent of root caries among caries-active adults enrolled in the Xylitol for Adult Caries Trial (X-ACT)

**André V. Ritter,**

University of North Carolina at Chapel Hill School of Dentistry, 433 Brauer Hall, CB#7450, Chapel Hill, NC 27599-7450, USA

**John S. Preisser,**

University of North Carolina at Chapel Hill Gillings School of Global Public Health, Chapel Hill, NC, USA

**Yunro Chung,**

University of North Carolina at Chapel Hill Gillings School of Global Public Health, Chapel Hill, NC, USA

**James D. Bader,**

University of North Carolina at Chapel Hill School of Dentistry, 433 Brauer Hall, CB#7450, Chapel Hill, NC 27599-7450, USA

**Daniel A. Shugars,**

University of North Carolina at Chapel Hill School of Dentistry, 433 Brauer Hall, CB#7450, Chapel Hill, NC 27599-7450, USA

**Bennett T. Amaechi,**

University of Texas Health Sciences Center at San Antonio, San Antonio, TX, USA

**Sonia K. Makhija,**

University of Alabama School of Dentistry, Birmingham, AL, USA

**Kimberly A. Funkhouser,**

The Kaiser Permanente Center for Health Research, Portland, OR, USA

**William M. Vollmer,**

The Kaiser Permanente Center for Health Research, Portland, OR, USA

**X-ACT Collaborative Research Group**

### Abstract

**Objective**—This paper uses baseline data from a randomized clinical trial to evaluate cross-sectional indicators of root caries in caries-active adults.

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rittera@dentistry.unc.edu .

**Conflict of interest** The authors declare that they have no conflict of interest.

**Materials and methods**—Adults (21–80 years) having at least 12 erupted teeth and between one and ten caries lesions were enrolled. Participants ( $n=437$ ) received caries exams by trained, calibrated examiners and responded to baseline demographic and medical–dental questionnaires. We examined associations between baseline characteristics and (1) the presence of any root caries using Mantel–Haenszel hypothesis tests and odds ratio (OR) estimators and (2) the number of root surfaces with caries among study participants with exposed root surfaces ( $n=349$ ) using Mantel–Haenszel mean score tests and Mann–Whitney estimators.

**Results/conclusions**—Adjusting for study site and age, male gender [OR, 1.72; 95% confidence interval (CI), 1.08, 2.78], white race (OR, 2.39; 95% CI, 1.43, 3.98), recent dental visit (OR, 1.98; 95% CI, 1.07, 3.66), poor self-described oral health (OR, 2.65; 95% CI, 1.10, 6.39), and recent professional fluoride treatment (OR, 1.85; 95% CI, 1.06, 3.25) were significantly associated with increased odds to have any root caries, and study participants with exposed root surfaces characterized by male gender [Mann–Whitney probability estimate (MW)=0.57; 95% CI, 0.51, 0.63], white race (MW, 0.61; 0.55, 0.68), recent dental visit (MW, 0.58; 0.50, 0.67), poor self-described oral health (MW, 0.61; 0.53, 0.69), and flossing at least once per day (MW, 0.57; 95% CI, 0.51, 0.62) were significantly more likely to have a greater number of root surfaces with caries than a randomly selected study participant from their respective complementary subgroups (female gender, non-white, etc.).

**Clinical relevance**—Our findings may help identify individuals at higher root caries risk.

### Keywords

Root caries; Risk indicators; Risk model

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### Introduction

Despite the progress achieved in the last 20 years in advancing oral health and reducing dental caries rates, root caries remains a prevalent infectious disease and an important clinical problem [1-4]. Recent reports based on independent, longitudinal studies estimate an annual root caries incidence of 26–27% among older adults [5, 6]. Root caries is more prevalent in older adults than in younger adults [5, 7-10]. By 2050, the number of adults aged 60 and older on the planet will more than triple to nearly two billion, at which time the population of older persons will be larger than the population of children for the first time in human history [11]. As adults are living and retaining their teeth longer, more root surfaces become physiologically or pathologically exposed and consequently at risk [2, 5, 12-15]. Therefore, root caries is likely to become an increasing clinical problem in the next several decades.

Dental caries is a multifactorial disease primarily caused by a complex interaction between cariogenic bacteria and fermentable carbohydrates on the tooth surface over time [16-18]. Many host factors, including dental biofilm (plaque) adherence and dynamics, saliva characteristics, immune system response, access to fluoride, and diet, play a role in the establishment and development of dental caries. It is believed that risk for caries is modulated by physical, biological, environmental, behavioral, and lifestyle-related factors [19-22]. The specific contribution of each of these factors in the makeup of an individual's

or a population's root caries risk has not been adequately explored in multi-center studies of high-risk populations.

Knowing what risk indicators are significantly associated with root caries is important to design prevention programs in which available resources can be applied to those at elevated risk, maximizing the effectiveness of these programs. Recent studies show that ethnic origin, smoking, diabetes, gingival recession, age, and socioeconomic status are frequently associated with high caries prevalence [23-25]. Historically, analyses of cross-sectional studies of indicators of root caries have employed caries prevalence as the outcome measure [26-29]. Although this approach has yielded useful information, it may overlook predictors of disease severity or extent.

The aim of this paper is to identify associations between baseline characteristics and two different dependent measures: presence of any root caries and extent of root caries as given by the number of root surfaces with caries. Data from the Xylitol for Adult Caries Trial (X-ACT), a randomized clinical trial that includes data on dental caries, demographics, and oral and medical characteristics, were used. These data can provide insights into putative risk indicators for participants that may be at a higher risk for root caries.

## Methods

### Study design

X-ACT was a 3-year, randomized, double-blind, placebo-controlled, multi-center clinical trial that aimed to determine if daily use of xylitol mints reduced the coronal and root caries increment among caries-active adults [30]. After preliminary screening, enrollment, and run-in phases, a total of 691 adults were randomized at three clinical centers or study sites: The University of Alabama at Birmingham (UAB), The University of North Carolina at Chapel Hill (UNC), and The University of Texas Health Sciences Center at San Antonio (UTHSCSA). The Institutional Review Boards at the respective study sites reviewed and approved the study protocol, and all participants provided a written informed consent. Due to data irregularities that were uncovered at the UTHSCSA site, the study's Data Safety and Monitoring Board deemed that primary outcome analysis be limited to the UNC and UAB sites, although secondary analyses could use data from all three sites. The UTHSCSA caries examination data have not been called into question. The present analysis is therefore limited to only data from UNC and UAB ( $n=437$ ).

### Recruitment and inclusion and exclusion criteria

We recruited participants from our own dental school clinics, community dental clinics, and the general community [31]. To be eligible, participants had to be aged 21–80 years, have at least 12 teeth with exposed dental surfaces, and have one or more coronal or root caries lesions either at time of the baseline examination or documented within the past 12 months.

We excluded candidates if they had more than ten teeth with untreated caries lesions, a history of head and neck radiation, or were receiving long-term antibiotic therapy. We also excluded anyone with known allergy to xylitol or other mint components, serious illnesses,

dietary restrictions, or those planning to leave the catchment area prior to the end of the study.

### Oral examination

Trained and calibrated examiners (one primary examiner and a secondary examiner in each study site) performed a baseline oral exam of the teeth and supporting tissues for each participant in a standard dental operator equipped with dental light and air–water syringe [32]. Examiners used a dental mirror and a Community Periodontal Index of Treatment Needs dental probe for the exams. Magnifying loupes were used at the discretion of the examiner. Radiographs were not used. With the help of a trained study recorder, examiners recorded coronal and root surfaces missing, sound, carious, restored, or sealed, as well as surfaces that were unable to be scored. Restored and sealed surfaces with caries were also recorded as such. Root surfaces were anatomically defined as those surfaces apical to the cementoenamel junction (CEJ).

The root caries classification system used was a modification of the International Caries Detection and Assessment System (ICDAS II) [33], summarized as follows:

- D1: non-cavitated lesion (clearly defined color change or loss of surface integrity less than 0.5 mm deep)
- D2: cavitated lesion (loss of surface integrity more than or equal to 0.5 mm deep)
- FD1: non-cavitated lesion (D1) adjacent to a restoration
- FD2: cavitated lesion (D2) adjacent to a restoration
- F: restored (filled) surface

From this information, we defined two root caries indicators: the presence of any root caries or restorations (D1, D2, FD1, FD2, or F) at baseline, and the number of root surfaces with caries or restorations. We similarly identified the presence of any coronal caries or restorations and a coronal caries index (CCI), defined as the number of coronal surfaces with caries or restorations divided by the total number of coronal surfaces at risk. Coronal caries was defined as any surface coronal to the CEJ with a restoration, a cavitated lesion, or a non-cavitated lesion, including lesions on previously restored surfaces.

### Questionnaire data

Participants completed a series of baseline questionnaires that included information on demographics (including age, sex, race, and body mass index), medical history, and dental and oral health. Medical history items included history of high blood pressure; history of cancer chemotherapy or radiotherapy; history of diabetes; history of depression; and current use of antibiotics, tranquilizers, or antihistamines. Dental and oral health items included: time since last dental visit (less than 1 year, 1 year or more); time of most recent professional fluoride treatment (1 year or less, more than 1 year, never); daily use of over-the-counter (OTC) fluoride toothpaste (yes, no); daily use of OTC fluoride mouthwash (yes, no); frequency of tooth brushing in a typical day (once a day or less, more than once a day); frequency of dental flossing in a typical day (less than once a day, once a day or

more); number of remaining teeth; self-described oral health (poor/very poor, fair, good, very good/excellent); and self-reported dry mouth symptoms (yes, no). Finally, we captured daily average consumption of mints/candy/gum (zero, one, two, three, or more exposures; these will be hereafter described simply as mints).

### Statistical analyses

Associations of baseline characteristics with presence of any root caries among the study population and number of root surfaces with caries among those with exposed root surfaces were evaluated for statistical significance with Mantel–Haenszel hypothesis tests [34, 35], adjusting for study site. Additional tests of association of risk factors with the number of root surfaces with caries adjusting for study site and the number of exposed root surfaces used an extended Mantel–Haenszel procedure called nonparametric analysis of covariance [36, 37]. Row and column scores for these hypothesis tests were chosen according to the measurement scale (dichotomous, nominal, or ordinal) of the risk factors and response variable as reported in the tables.

The magnitude of the effects of risk factors with Mantel–Haenszel  $p$  values less than 0.10 was then quantified using Mantel–Haenszel odds ratio (OR) estimators for the strength of the association of risk factors with the presence of any root caries and Mann–Whitney rank measures of association estimators [38, 39] for the association of dichotomous (or dichotomized) risk factors with the number of root surfaces with caries. The Mann–Whitney estimator, which is a version of the Goodman–Kruskal rank correlation coefficient for ordinal variables when one of the two variables is dichotomous, gives the probability that a randomly selected study participant from one subgroup defined by a baseline dichotomous characteristic (e.g., female) had a greater number of root surfaces with caries than a randomly selected study participant from the complementary subgroup (e.g., male). Odds ratios and Mann–Whitney probabilities were stratified estimators, adjusting for study site and age (60 years or less vs. more than 60). An additional set of odds ratios additionally adjusted for the number of remaining teeth (26 or less vs. more than 26), and a further set of Mann–Whitney estimators simultaneously adjusted for study site and the number of remaining teeth; the Mann–Whitney methodology precluded adjustment for more than two risk factors at a time in these data. For estimation (but not for hypothesis tests), risk factors with three or more categories were dichotomized. We dichotomized all categorical risk indicators that passed an initial screening criterion of a Mantel–Haenszel  $p < 0.10$ . Specifically, we combined black with other race for comparison with white/Caucasian, 0/1 mints vs. 2/3 mints, and the second and third categories of time of most recent professional fluoride treatment were combined to create an indicator variable for fluoride treatment in the past year. Finally, the first three categories of “self-described oral health” (“poor/very poor,” “fair,” and “good”) were combined to create an indicator variable for very good/excellent oral health. SAS v. 9.2 was used for statistical analysis [40].

### Results

The characteristics of the study participants by study site are summarized in Table 1. Four hundred thirty-seven caries-active adults participated in the study. The mean age for the

entire sample was 48 (SD, 13; range, 21–80) years, while the mean number of remaining teeth was 25 (SD, 4; range, 11–32) teeth. The percentage of study subjects with any root caries was 46% and varied greatly between sites with higher prevalence noted at UNC (63%) than at UAB (26%). The mean number of exposed root surfaces was 12.2 (SD, 12.6; range, 0 to 64) and, among those with any exposed root surfaces ( $n=349$ ), the mean number of root surfaces with caries was 2.70 (SD, 4.39; range, 0 to 29). Non-cavitated root carious surfaces (D1s and FD1s) contributed substantially to the root caries crude prevalence: 30.7% participants had D1 root lesions and 6.4% had FD1 root lesions, whereas 19.9% had D2 root lesions and 4.8% had FD2 root lesions. Approximately 26.5% participants had restored root surfaces with no current root caries.

Female/male ratio and race varied considerably across study sites, with the UAB site having larger percentages of females and African-Americans than the UNC site. Important differences were also noted in some dental and oral health variables, such as daily average mints/candy/gum consumption, timing of most recent dental visit, and timing of most recent professional fluoride application.

Bivariate associations for continuous and categorical variables with the presence of any root caries adjusting for study site as evaluated by Mantel–Haenszel tests are shown in Tables 2 and 3, respectively. In these analyses, increasing age, decreasing number of remaining teeth, increasing CCI, male gender, white/Caucasian race, high blood pressure, more recent dental visit, more recent professional fluoride treatment, and dry mouth symptoms were significantly associated with having any root caries ( $p<0.05$ ). In the analysis of Mantel–Haenszel odds ratio estimators for stratified 2×2 tables, male gender [OR, 1.72; 95% confidence interval (CI), 1.08, 2.78], white race (OR, 2.39; 95% CI, 1.43, 3.98), recent dental visit (OR, 1.98; 95% CI, 1.07, 3.66), poor self-described oral health (OR, 3.65; 95% CI, 1.51, 8.81), and recent professional fluoride treatment (OR, 1.85; 95% CI, 1.06, 3.25) were significantly associated with increased odds to have any root caries, adjusting for study site and age (Table 4). When odds ratio estimators additionally adjusted for the number of remaining teeth, recent professional fluoride treatment became nonsignificant, while the odds ratios for the other significant risk factors in Table 4 remained significant and changed little.

Bivariate associations for continuous and categorical variables with number of root surfaces with caries adjusting for study site among participants with any exposed root surfaces ( $n=349$ ) as evaluated by Mantel–Haenszel tests are shown in Tables 2 and 5, respectively. In these analyses, increasing age, decreasing number of remaining teeth, decreasing BMI, increasing CCI, male gender, white/Caucasian race, high blood pressure, more recent dental visit, and daily flossing frequency were associated with the extent of root caries or the number of root surfaces with caries ( $p<0.05$ ; second to last columns in Tables 2 and 5). Daily average mints/candy/gum and self-described oral health were nearly significant. After adjustment for the number of exposed root surfaces with nonparametric analysis of co-variance, decreasing number of remaining teeth and increasing CCI were associated with the extent of root caries or the number of root surfaces with caries (last column in Table 2), while none of the factors in Table 5 remained significant (last column in Table 6).

In the analysis of Mann–Whitney estimators for stratified  $2 \times r$  tables (where  $r$  is the number of distinct values taken by the response variable that is the number of root surfaces with caries; Table 6), several risk factors were significantly associated with the number of root surfaces with caries. Adjusting for study site and age, study participants with exposed root surfaces characterized by male gender [Mann–Whitney probability estimate (MW)=0.57; 95% CI, 0.51, 0.63], white race (MW, 0.61; 0.55, 0.68), recent dental visit (MW, 0.584; 0.501, 0.667), poor self-described oral health (MW, 0.61; 0.53, 0.69), and flossing at least once per day (MW, 0.57; 95% CI, 0.51, 0.62) had a significantly greater than 0.5 probability (i.e., 0.5 meaning there are no group differences) to have a greater number of root surfaces with caries than a randomly selected study participant from their respective complementary subgroups (female gender, non-white, etc.; Table 6). For example, a randomly selected study participant who visited a dentist in the last year is estimated to have a probability of 0.58 (95% CI, 0.50, 0.67) of having more root surfaces with caries than a randomly selected study participant who did not visit a dentist in the last year. When the Mann–Whitney estimators adjusted for study site and the number of remaining teeth, flossing at least once a day was no longer significant, while the odds ratios for the other significant risk factors in Table 6 remained significant and changed little.

## Discussion

Root caries is an increasing clinical problem. The study of risk indicators associated with the presence of any root caries provides insights into root caries etiology. Moreover, the examination of caries extent as the number of root surfaces with caries has the potential to provide more discriminative information on root caries risk. The identification of variables significantly associated with root caries presence and extent can also help identify which individuals or groups of individuals are best candidates for targeted prevention. X-ACT provides a unique opportunity to study root caries risk indicators, given that it enrolled only caries-active adults who had at least one recent coronal or root caries lesion within the last 12 months. In addition, being a multi-center trial, it can potentially result in findings that can be more generalizable than single-center clinical trials with a more homogeneous sample. However, the “target” population the X-ACT trial participants represent is elusive given the nonrandom enrollment of a high-risk caries population based on special selection criteria. Because most X-ACT participants had coronal caries (see coronal caries prevalence, Table 1), the results presented in this paper can inform identification of high root caries risk individuals only within a caries-active population.

This study used a nonparametric statistical analysis approach based on Mantel–Haenszel hypothesis tests that make minimal assumptions about the sampling process and distributional properties of the root caries data. Mantel–Haenszel tests are a common choice for the statistical analysis of data from clinical trials whose study populations, like the X-ACT study population, are samples of convenience with subjects meeting very specific entrance criteria. In other words, the X-ACT study population was not obtained via random sampling (or even as an easily recognizable “representative” sample of some external population) so that random sampling-based methods such as logistic regression are not easily justified in our setting. Though their use is well justified, Mantel–Haenszel tests have the limitation that inference arising from their use has strict application only to the

finite population of the X-ACT caries trial population, and extrapolation beyond requires non-sampling arguments. However, the ability to compute confidence intervals for odds ratios and rank association measures (Tables 4 and 6, respectively) depends upon stronger assumptions.

Although number of teeth has been found to be associated with root caries in previous studies [2, 41-44], the directionality of the association is not always the same. Having more teeth implies more surfaces at risk, but may also indicate good oral health and hence less root caries risk. Additionally, individuals with lower numbers of teeth may have lost teeth due to root caries. These factors make it difficult to clearly establish the relationship between number of teeth and root caries risk, and to make any firm recommendations for caries risk assessment and prescription of preventive strategies based on this variable alone. Therefore, our approach was to use number of remaining teeth as an adjustment factor rather than as a risk factor. We did not consider coronal caries index as either a risk factor or adjustment factor for root caries as it was strongly correlated with root caries and it would more properly be considered an outcome variable.

In this study, males were more likely than females to have any root caries adjusting for study site (Table 3), and males had a significantly greater number of root surfaces with caries than females adjusting for study site and number of root surfaces at risk (Table 5); similar results were obtained using stratified odds ratio and Mann–Whitney estimators adjusting for study site, age, and/or number of remaining teeth (Tables 4 and 6). The stratified analysis methods used in this paper preclude use of more than a few variables for covariate adjustment. Nonetheless, gender differences persisted after adjustment for race (not shown). The available literature is not conclusive on gender as a risk indicator [45-54]. Differences between males and females in terms of the other explanatory variables (demographics, medical, dental, education, socioeconomic, etc.) merit further study for confounding factors that may help explain gender risk differences as there seems to be no logical biological reason for these differences.

Race and ethnic background have been found to be risk indicators for root caries in previous studies [50, 51, 55-57]. While Ringelberg and colleagues [51] and Winn and colleagues [50] reported an increased risk for non-Hispanic blacks, one other longitudinal study reported that blacks were at lower risk compared to whites [56]. One study including Asians reported an increased caries risk for that race group [55]. In our study, white participants were more likely to have any root caries than those of other races when adjusting for study site and age category (Table 4). When also adjusting for number of remaining teeth, white race remained significant. Among participants with root surfaces at risk, whites were also more likely to have a greater number of root surfaces with caries when compared to those of other races, when adjusting for study site and age (Table 6), or study site and number of remaining teeth. As noted in Table 1, race was not evenly distributed throughout the study sites. African-Americans were mostly concentrated at UAB, while the majority of white/Caucasians were enrolled at UNC. These different distributions may influence the analyses, and future studies of risk prediction based on race (and ethnic origin) should attempt to more carefully balance these factors across multiple study sites.



Participants who had been to the dentist within the year prior to baseline had higher rates of any root caries (Table 3) and a greater number of root surfaces with caries (Table 5) than participants who had not been to the dentist within the last year. Additionally, participants who had been to the dentist within the year had a greater number of exposed root surfaces, but the number of root surfaces with caries was not significantly associated with time since last dental visit adjusting for the number of exposed root surfaces. Although this may be an artifact of the effect of the UNC site having a large proportion of the participants with root caries and under active dental care, one other study also reported that participants who visited the dentist in the previous year were more likely to have root caries than those who did not [23]. This hardly indicates that going to the dentist is a risk factor for root caries, but may indicate that individuals (at least those in our study) still visit the dentist more for curative rather than for preventive reasons.

This study is limited by the cross-sectional nature of the data, which precludes establishing definitive causal relationships between the exposure and outcome variables. Moreover, the study eligibility criteria and the nonrandom manner in which participants were recruited both limit the generalizability of our results. Another limitation is the moderately narrow scope of the information on putative risk indicators available in the database. For example, no information was available on plaque index and composition, saliva characteristics (pH, buffer capacity, flow rate, and microbiological content), smoking, and dietary habits, all of which are known to be associated with root caries [58].

Additionally, the substantial demographic differences between study sites can be both a strength and a weakness of the study. Although these differences provide insights into putative root caries risk indicators in diverse populations, the heterogeneous nature of the combined data can limit the interpretation of the analyses. This limitation should be considered when comparing our results to those of other studies, especially those based on random population samples, as ours is a highly selected sample. Additionally, we cannot rule out confounding effects that we did not measure (e.g., diet and fluoridated water). The study participants are being followed annually, and future studies will explore whether the observed baseline risk indicators will maintain their relevance or if other indicators are revealed.

Although it is an accepted epidemiological approach, the inclusion of non-carious restored (F) surfaces as caries events likely overestimates root caries prevalence. One study found that as much as 65% of the root caries increment can be due to restored surfaces [59]. Counting restorations as caries does not accurately reflect the carious state of that surface at the time of the examination. Furthermore, not all root restorations are placed due to caries. It has been reported that as many as 55% of the restorations on buccal root surfaces are due to non-carious defects [60]. However, most caries indices, including DMFS and extent (number of root surfaces with caries), count restorations (F surfaces) as caries events, and this was the method we elected to use so that our results could be more easily contrasted with previous findings employing a similar methodology. The ICDAS caries classification system may afford the opportunity to avoid the problematic inclusion of the F and M components as “markers” of caries [61]. In our study, if F surfaces were not included as caries events in the prevalence and extent calculations, we would obtain a prevalence of 37% and mean number

of root surfaces with caries of 1.7. This represents a 20% decrease in prevalence and a 38% decrease in mean number of root surfaces with caries from what we reported.

In conclusion, the analyses of the baseline data available from X-ACT study participants in two clinical centers indicated that, adjusting for study site and age, male gender, white race, recent dental visit, and poor self-described oral health were significantly associated with increased odds to have any root caries and with greater chance to have an increased number of root surfaces with caries. In contrast, participants with recent professional fluoride treatment had greater odds of any caries, while participants who reported flossing at least once a day had greater chance to have an increased number of root surfaces with caries. These baseline associations will be explored further in longitudinal analyses of these participants and risk indicators. Future studies of root caries risk should develop and validate risk models in large longitudinal studies of high-risk participants.

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**Table 1**

Characteristics of the study participants across study sites (N=437)

Variable	UAB (n=194)		UNC (n=243)	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age, years	47.1 (13.6)	49.1 (13.3)		
BMI, kg/m <sup>2</sup>	30.4 (7.7)	28.4 (6.5)		
Number of remaining teeth	25.8 (4.0)	25.3 (3.7)		
Number of root surfaces with caries (extent)	0.6 (1.5)	3.4 (5.0)		
Number of exposed root surfaces	8.9 (11.4)	14.9 (12.8)		
Coronal caries index	16.3 (10.5)	32.7 (15.8)		
<b>Variable</b>	%	%	%	%
Root caries (prevalence) <sup>a</sup>	26	63	Yes	63
Coronal caries (prevalence)	99	100	Yes	100
Gender	68	55	Female	55
Race	38	77	White/Caucasian	77
	58	17	African-American	17
	4	7	Other race	7
Ethnic origin	4	3	Hispanic	3
Daily average mints/candy/gum consumption	38	28	0	28
	12	26	1	26
	13	20	2	20
	37	25	3	25
High blood pressure	35	30	Yes	30
Cancer chemo/radiotherapy	6	7	Yes	7
Diabetes	12	15	Yes	15
Depression	18	17	Yes	17
Medications <sup>b</sup>	8	14	Yes	14
Time since last dental visit	58	93	<1 year	93
Time of most recent professional fluoride treatment	29	74	1 year	74
	40	23	>1 year	23
	31	4	Never	4

	UAB (n=194)	UNC (n=243)
Daily use of OTC fluoride toothpaste	92	90
Daily use of OTC fluoride mouthwash	42	35
Daily frequency of toothbrushing	Once/day	25
Daily frequency of flossing	<Once/day	43
Self-described oral health	Poor/very poor	14
	Fair	37
	Good	35
	Very good/excellent	14
Dry mouth symptoms	72	74

The item *daily average mints/candy/gum consumption* was not collected for all participants (n=327)

*OTC over-the-counter*

<sup>a</sup>The sample sizes for groups at risk for root caries (i.e., participants with exposed root surfaces) are 126 for UAB and 223 for UNC

<sup>b</sup>Use of antibiotics, tranquilizers, or antihistamines

Means of continuous variables for participants with and without any surfaces with root caries and rank correlation of those variables with the number of surfaces with root caries, among those with exposed root surfaces, adjusted for study site

**Table 2**

Variable	Mean (SD), participants with root caries (n=202)	Mean (SD), participants without root caries (n=235)	p value <sup>a</sup>	Correlation (SD) with number of surfaces with root caries (unadjusted) <sup>b</sup> (n=349)	Correlation (SD) with number of surfaces with root caries (adjusted) <sup>c</sup> (n=349)
Age, years	55.0 (10.8)	42.3 (12.8)	<0.001	0.33 (0.05)**	0.11 (0.05)
Number of remaining teeth	24.3 (3.8)	26.5 (3.5)	<0.001	-0.25 (0.05)**	-0.17 (0.05)*
BMI, kg/m <sup>2</sup>	28.5 (6.1)	30.0 (7.9)	0.44	-0.14 (0.05)*	-0.06 (0.06)
Coronal caries index	33.0 (16.1)	18.8 (12.6)	<0.001	0.47 (0.04)**	0.48 (0.04)**

\*  $p < 0.01$

\*\*  $p < 0.001$

<sup>a</sup> Mantel-Haenszel correlation statistic with standardized midrank scores adjusting for study site;

<sup>b</sup> Spearman correlation coefficient

<sup>c</sup> Partial Spearman correlation coefficient adjusted for number of exposed root surfaces



**Table 3**  
Association of categorical variables with any root caries, with *p* values adjusted for study site

Variable	<i>N</i>	Percent with root caries	<i>p</i> <sup>b</sup> value
Gender			
Female	265	38.5	0.001
Male	172	58.1	
Race			
White/Caucasian	260	58.5	<0.001
African-American	153	26.1	
Other	24	41.7	
Ethnic origin			
Hispanic	15	40.0	0.647
Not Hispanic	422	46.5	
Daily average mints/candy/gum consumption			
0	108	46.3	0.260 <sup>c</sup>
1	62	51.6	
2	55	45.5	
3	102	39.2	
High blood pressure			
Yes	139	54.7	0.002
No	298	42.3	
Cancer chemo/radiotherapy			
Yes	28	57.1	0.224
No	409	45.5	
Diabetes			
Yes	59	54.2	0.287
No	378	45.0	
Depression			
Yes	75	50.7	0.327
No	362	45.3	
Medications <sup>d</sup>			
Yes	50	60.0	0.174
No	387	44.4	
Time since last dental visit			
<1 year	336	53.0	0.016
1 year	96	22.9	
Time of most recent professional fluoride treatment			
1 year ago	195	58.5	0.015 <sup>c</sup>
>1 year ago	108	35.2	
Never	56	26.8	
Daily use of OTC fluoride toothpaste			
Yes	375	47.5	0.248
No	39	41.0	

Variable		N	Percent with root caries	<i>p</i> value
Daily use of OTC fluoride mouthwash	Yes	156	43.6	0.715
	No	255	47.8	
Daily frequency of toothbrushing	Once/day	115	40.0	0.139
	>Once/day	319	48.6	
	<Once/day	204	40.2	
Daily frequency of flossing	Once/day	230	51.7	0.056
	Poor/very poor	74	39.2	
Self-described oral health	Fair	163	50.9	0.186 <sup>c</sup>
	Good	148	50.0	
	Very good/excellent	48	31.3	
	Yes	316	49.7	
Dry mouth symptoms	Yes	316	49.7	0.025
	No	117	37.6	

*OTC over-the-counter*

<sup>a</sup>Use of antibiotics, tranquilizers, and/or antihistamines

<sup>b</sup>Based on Mantel–Haenszel General Association Statistic (which is approximately equivalent to the Pearson chi-square statistic), unless otherwise noted

<sup>c</sup>Mantel–Haenszel Correlation Statistic with standardized midrank scores; the Mantel–Haenszel General Association *p* value for self-described oral health (as a nominal variable) was 0.01

**Table 4**

Mantel–Haenszel odds ratio estimates (95% CI) for association of risk factors with any root caries adjusting for study site; study site and age; or study site and age ( $n=437$ )

Variable	Adjusted for <i>study site</i> , OR (95% CI)	Adjusted for <i>study site and age</i> , OR (95% CI)
Male	<b>2.00 (1.30, 3.03)</b>	<b>1.72 (1.08, 2.78)</b>
White/Caucasian	<b>2.34 (1.50, 3.65)</b>	<b>2.39 (1.43, 3.98)</b>
Daily mints <sup>2</sup>	0.79 (0.49, 1.26)	1.16 (0.68, 1.97)
High blood pressure	<b>2.00 (1.28, 3.12)</b>	0.83 (0.49, 1.38)
Visited dentist in last year	<b>2.03 (1.14, 3.62)</b>	<b>1.98 (1.07, 3.66)</b>
Fluoride in last year <sup>a</sup>	<b>1.76 (1.08, 2.87)</b>	<b>1.85 (1.06, 3.25)</b>
Flossing once/day	1.49 (0.99, 2.25)	1.41 (0.89, 2.23)
Poor/fair/good oral health <sup>b</sup>	<b>3.17 (1.55, 6.49)</b>	<b>3.65 (1.51, 8.81)</b>
Dry mouth	<b>1.68 (1.06, 2.65)</b>	1.35 (0.80, 2.27)

Odds ratios statistically different than 1.0 at  $p < 0.05$  are in bold. For adjusted estimators, age categories were 60 years or less versus more than 60; number of remaining teeth was dichotomized with categories 26 teeth or less versus more than 26 teeth

<sup>a</sup>Whether most recent professional fluoride treatment was received in the last year

<sup>b</sup>Self-described oral health was dichotomized as very good or excellent versus poor/very poor, fair, or good

Association of individual characteristics with number of root surfaces with caries (RSC) among those with exposed root surfaces ( $n=349$ ), with  $p$  values adjusted for study site

Table 5

Variable	N	Mean RSC	$p^b$ value	$p^d$ value
Gender				
Female	197	2.02	0.004	0.281
Male	152	3.58		
Race				
White/Caucasian	225	3.47	0.002	0.143
African-American	103	1.04		
Other	21	2.57		
Ethnic origin				
Hispanic	13	1.23	0.263	0.077
Not Hispanic	336	2.75		
Daily average mints/candy/gum consumption				
0	87	2.56	0.073 <sup>c</sup>	0.585 <sup>c</sup>
1	50	2.94		
2	41	4.17		
3	81	1.78		
High blood pressure				
Yes	121	3.04	0.026	0.454
No	228	2.51		
Cancer chemo/radiotherapy				
Yes	25	3.24	0.233	0.218
No	324	2.65		
Diabetes				
Yes	53	2.25	0.854	0.944
No	296	2.78		
Depression				
Yes	64	2.97	0.294	0.940
No	285	2.64		
Medications <sup>d</sup>				
Yes	42	3.14	0.678	0.263
No	307	2.64		
Time since last dental visit				
<1 year	277	3.09	0.016	0.800
1 year	68	1.21		
Time of most recent professional fluoride treatment				
1 year ago	171	3.47	0.217 <sup>c</sup>	0.415 <sup>c</sup>
>1 year ago	76	1.95		
Never	41	1.29		
Daily use of OTC fluoride toothpaste				
Yes	301	2.75	0.599	0.300

Variable	N	Mean RSC	$p^b$ value	$p^d$ value
Daily use of OTC fluoride mouthwash	No	2.75		
	Yes	2.75	0.959	0.220
Daily frequency of toothbrushing	No	2.63		
	Once/day	2.42	0.416	0.993
Daily frequency of flossing	>Once/day	2.8		
	<Once/day	2.11	0.024	0.550
Self-described oral health	Once/day	3.19		
	Poor/very poor	3.71	0.080 <sup>c</sup>	0.128 <sup>c</sup>
Dry mouth symptoms	Fair	2.87		
	Good	2.45		
	Very good/excellent	1.29		
	Yes	2.77	0.366	0.063
	No	2.51		

OTC over-the-counter

<sup>a</sup>Use of antibiotics, tranquilizers, and/or antihistamines

<sup>b</sup>Based on Mantel–Haenszel Mean Score Statistic with standardized midrank scores adjusting for study site unless otherwise noted

<sup>c</sup>Mantel–Haenszel Correlation Statistic with standardized midrank scores adjusting for study site

<sup>d</sup>Mantel–Haenszel test adjusting for study site and for number of root surfaces with caries at risk via nonparametric analysis of covariance

**Table 6**

Mann–Whitney (MW) estimators of the probability that a randomly selected participant from the subgroup listed will have a greater number of root surfaces with caries than a randomly selected person for the complementary group not listed ( $n=349$ )

Variable	Adjusted for <i>study site</i> , MW (95% CI)	Adjusted for <i>study site and age</i> , MW (95% CI)
Male	<b>0.58 (0.53, 0.64)</b>	<b>0.57 (0.51, 0.63)</b>
White/Caucasian	<b>0.61 (0.55, 0.68)</b>	<b>0.61 (0.55, 0.68)</b>
Daily mints 2	0.46 (0.39, 0.52)	0.49 (0.42, 0.56)
High blood pressure	<b>0.57 (0.51, 0.63)</b>	0.53 (0.46, 0.59)
Visited dentist in last year	<b>0.60 (0.52, 0.67)</b>	<b>0.58 (0.50, 0.67) <sup>c</sup></b>
Fluoride in last year <sup>a</sup>	0.53 (0.46, 0.61)	0.54 (0.47, 0.61)
Flossing once/day	<b>0.57 (0.51, 0.62)</b>	<b>0.57 (0.51, 0.62)</b>
Poor/fair/good oral health <sup>b</sup>	<b>0.66 (0.59, 0.74)</b>	<b>0.61 (0.53, 0.69)</b>
Dry mouth	0.53 (0.46, 0.60)	0.53 (0.46, 0.59)

Mann–Whitney probabilities statistically different than 0.5 at  $p<0.05$  are in bold. For adjusted estimators, age was dichotomized with categories 60 years of less versus more than 60; number of remaining teeth was dichotomized with categories 26 teeth or less versus more than 26 teeth

<sup>a</sup>Whether most recent professional fluoride treatment was received in the last year; for this variable, the estimate that adjusted for age did not adjust for site due to sparse data

<sup>b</sup>Self-described oral health was dichotomized as very good or excellent versus poor/very poor, fair, or good

<sup>c</sup>The estimate 0.584 is considered statistically significant because its confidence interval (0.501, 0.667) excludes 0.500