Published in final edited form as:

Community Dent Oral Epidemiol. 2010 December ; 38(6): 487–497. doi:10.1111/j.1600-0528.2010.00555.x.

Clinical and community risk models of incident tooth loss in postmenopausal women from the Buffalo Osteo Perio Study

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Abstract

Objectives—While risk factors for tooth loss in adults have been identified, limited studies describing factors associated with incident tooth loss in postmenopausal women exist. This study assessed both clinical and non-clinical risk factors for incident tooth loss.

Methods—Postmenopausal women (N= 1,341) were recruited between 1997–2000 from 1847 eligible Observational Study participants of the Buffalo, NY center of the Women's Health Initiative who had complete dental examinations to assess alveolar bone height, soft tissue attachment and general oral health, and completed questionnaires concerning demographics, general health, lifestyle and oral health (72.6% participation rate). Five years later (2002–2005), 1021 women (76.1%) repeated these examinations and questionnaires. Incident tooth loss was determined by oral examination

Results—After an average 5.1 years of follow-up (SD, 0.38), a total of 323 teeth were lost in 293 women, resulting in 28.7% of women with incident loss of at least one tooth. In multivariable models, diabetes history, gum disease history, smoking, previous tooth loss, BMI and plaque index, baseline clinical measures including alveolar crestal height (ACH) (OR=1.22 per mm loss, 95% CI 1.11, 1.35), clinical attachment loss (CAL) (OR=1.13 per mm loss, 95% CI 1.05, 1.23) and pocket depth (PD) (OR=1.26 per mm loss, 95% CI 1.13, 1.41) were significant risk factors of incident tooth loss. In a community model that included no clinical measures, diabetes history (OR=2.45, 95% CI 1.26, 4.77), prior gum disease (OR=1.97, 95% CI 1.43, 2.70), ever smoking (OR=1.42, 95% CI 1.06, 1.89), number of teeth lost at baseline (OR=1.05 per tooth, 95% CI 1.02, 1.08) and BMI (OR=1.15 per 5 km/m² increase, 95% CI 1.01, 1.33) were associated with an increased risk of incident tooth loss.

Conclusions—Clinical and questionnaire based models were found to provide similar risk estimates for incident tooth loss in postmenopausal women. These models identified high risk postmenopausal women where preventive strategies may be targeted.

Introduction

Tooth loss is associated with problems for people at any age, including significant morbidity among older adults. Tooth loss affects quality of life and chronic conditions such as heart disease, diabetes and even mortality (1–5). As a result, partial and complete edentulism in older men and women may pose a significant public health problem in the United States as the population ages. Greater emphasis on improving oral health has been suggested (6–8). Understanding factors that are associated with incident tooth loss will aid in developing these prevention strategies. To this end, associations of numerous exposures and tooth loss have been explored and include various demographic, lifestyle and clinical characteristics (9–13). Some studies have explored incident tooth loss among adults (14–17), where risk increases with age and postmenopausal status, the latter potentially due to factors such as bone loss and estrogen deficiency (18,19). Despite having better oral health than men, women more often experience tooth loss (20–22). Longitudinal studies of incident tooth loss among postmenopausal women are limited (23,24). The purpose of this study was to evaluate a series of clinical and non-clinical models of risk factors of incident tooth loss in postmenopausal women, and identify those which could be informative to researchers studying this population or to clinicians managing their patients. We hypothesized that certain clinical and personal characteristics could characterize those women at greater risk of tooth loss.

Methods

Sample

This study was conducted in participants of the Women's Health Initiative Observational Study (WHIOS) enrolled at the University at Buffalo clinical center (N=2249) (Figure 1). These postmenopausal women were contacted between 1997–2000 and invited to participate in an ancillary study of osteoporosis and oral bone loss (Osteo Perio Ancillary Study) (25). Those interested and eligible completed a series of questionnaires, had an oral examination and underwent systemic bone density screening. A total of 1362 women participated in this ancillary study. Of those, 1341 who had complete baseline questionnaires (5 missing questionnaires) and oral radiographs (16 incomplete radiographs) were invited back approximately 5 years later for a follow-up study where questionnaire information and standardized examinations were repeated. Among the 1341 participants from the baseline study invited to the follow-up examination, 101 were ineligible, 51 were determined to be deceased, 151 were not interested in participating, 3 withdrew from the original WHI observational study, and 9 were unable to be contacted. An additional 5 consented but had an incomplete dental exam at the follow-up visit. These analyses are based on the remaining 1,021 individuals who participated in the follow-up study. Participants were ineligible for the baseline study if they had less than 6 teeth remaining, history of bone disease, bilateral hip replacement, cancer diagnosis in the 10 years prior to interview, and certain other serious illnesses (25). For the follow-up study, women were ineligible if during the follow-up they developed cancer or an immunosuppressive disorder (eg. transplant recipient), were on long term antibiotic treatment or received recent dental x-rays within the prior year. All participants provided signed informed consent for the WHI-OS, as well as the baseline and follow-up ancillary studies. All studies were approved by the University at Buffalo's Health Sciences Institutional Review Board.

Interview

At both the baseline and follow-up visits, participants provided self-reported responses to lifestyle and demographic questionnaires, had physical measures taken, completed a bone density assessment and had an oral examination (25,26). All questionnaires and

examinations were conducted using standardized protocols. Demographic and other variables to be examined included age, self described race/ethnicity (American Indian/Alaskan Native, Asian/Pacific Islander, Black or African American, Hispanic/Latino, White), education level (high school or less, college, graduate school), marital status (never married, divorced/separated, widowed, currently married, marriage-like relation), income (less than \$10,000, \$10–19,999, \$20–34,999, \$35–49,999, \$50–74,999, \$75–99,999, \$100,000 or more), cigarette smoking (ever/never), frequency of brushing (≤ 1 times per day, ≥ 2 times per day), flossing (daily, > 1 time per week, 1 time per week, not every week) and dental visits (only with a problem or never, ≥ 1 time per year), body mass index (BMI in kilograms/meter²), type 2 diabetes history (yes or no), years since menopause without use of hormone therapy (HT), current HT use (yes or no), current HT and/or bone drug use, worst T-score category from DXA of all sites measured (normal, $T \geq -1$, osteopenia, $-2.5 \leq T < -1$, osteoporosis, $T \leq -2.5$), tooth loss at baseline (any, none), number of teeth remaining at baseline visit, history of surgery for gum disease (ever, never) and history of tooth extraction at baseline due to gum disease (ever, never).

Clinical Exam

Tooth presence was recorded as part of oral examination by a dental examiner both at baseline and follow-up. For the purpose of these analyses, tooth loss was defined as determination of no tooth present at follow-up that was present at baseline examination. The primary outcome for these analyses was the dichotomous variable indicating any tooth loss (Yes/No) during the study period. The oral examination included oral radiographs for determination of alveolar crestal height (ACH). ACH was measured in all teeth present in up to 48 sites from 24 teeth from 11 oral radiographs using a method developed by Hausmann et al (27–29). Radiographs were digitized and ACH was measured as the distance in millimeters from the cemento-enamel junction to the most coronal part of the alveolar crest in a plane parallel to the long axis of the tooth for 2 sites per tooth. Larger ACH values represent worse bone loss. Three ACH measures were created from these data: whole mouth mean (mm) of all sites measured, worst site measured (mm) and number of sites measured with loss of 4mm or greater. Probing pocket depth (PPD) was measured in millimeters using a constant force probe (The Florida Probe System®, Gainesville, FL). Inter- and intra-examiner reliability of the PPD measurements have been previously reported to be within 0.5mm (30) and 0.57 mm intra-examiner reliability of clinical attachment loss (CAL) (31). Internal quality control of ACH measures revealed a coefficient of variation of 5%. Clinical attachment loss (CAL) was measured by subtracting the distance between the cemento-enamel junction and the gingival margin from PPD in millimeters (26). For both PPD and CAL six sites per tooth were measured. Whole mouth (mean) and worst site measured were created using all sites for CAL and PPD. Calculus presence per tooth was assessed on examination, recorded as absent, supragingival only or supragingival and/or subgingival and used here as whole mouth mean in all teeth assessed. Plaque and gingival bleeding were recorded as absent or present on 3 sites per tooth, expressed as mean (%) of the whole mouth. Presence of gingival bleeding was assessed using a Michigan O periodontal probe inserted at each site and recorded as present or absent. Reasons for tooth loss were self-report during the oral examination on query of the dental examiner for each tooth noted missing on examination. Recorded reasons included accident, caries, congenitally missing, ortho/malposed, periodontal disease, unerupted, root canal and unable to determine.

Statistical Analyses

The analytic strategy included a review of the published literature and identification of factors that were known or suspected as risk factors for tooth loss. Those factors that were available in our dataset were considered in the analysis. Following this selection, we determined univariate statistical associations of these study variables for incident tooth loss

(Yes/No) using Student's t-test or Pearson's Chi square. Risk factors found to be associated with tooth loss in univariate analyses ($p \leq 0.20$) were attempted in a series of multivariate logistic regression models. We chose to use logistic regression because the outcome of interest is dichotomous (any tooth loss, yes or no) and logistic regression is an appropriate model for binary outcomes. Four models were created. Three of the models were clinically based with one model built for each clinical measure (ACH, CAL, PPD) separately as the main independent variable, and then determining which other variables identified in univariate analyses added significantly to these models. A 4th model was built attempting only those variables identified in the univariate analyses that could be assessed without a clinical oral examination, described as the "community" model. Forward stepwise logistic regression was used to create these models, attempting entry at a significance level of $p = 0.20$ and removal at $p = 0.05$. Each step of a regression model was assessed against the others by comparing the changes in the individual significance of the independent variables. This approach incorporated a priori knowledge of known, important risk factors as well as an objective selection of factors which were statistically significant. After all stepwise procedures were completed, models were re-run using the "enter" method to maximize the number of participants included in the final models, as a result of missing data for individuals who did not get included in the forward models. Using the same process, the community-based model was developed. The forward selection process allowed for a step-by-step assessment of the importance of each factor in contributing to the overall model. In each of the clinical models, ACH, CAL and PPD, only one clinical measure was included to avoid collinearity with the other related oral measures. Within our data set, correlations among the independent predictors other than ACH, CAL and PPD were all quite small to moderate, indicating a lack of multicollinearity. Linearity between continuous independent variables and tooth loss (dichotomous outcome) was assessed by regressing each individual predictor against the log odds of tooth loss for the entered independent variable. All statistical analyses were conducted using SPSS 15.0.1 for Windows.

Results

Study participant baseline characteristics are shown in Table 1. At baseline the mean number of teeth present per person was 23.5 (± 5.2 , range 6–28). While the baseline study required that only women with at least 6 teeth present were eligible, only 1% had this few teeth at enrollment and 91% began the study with more than half (16 to 28) of their teeth intact.

The most significant differences between those who lost any teeth and those who did not were seen in the proportion of ever-smokers (54% and 43%, respectively), higher mean BMI (27.4 compared to 26.2) and number of teeth at baseline (22.3 compared to 23.9); all $p \leq 0.001$. Other factors significantly associated with incident tooth loss included older age, lower frequency of dental visits, diabetes history, not currently using hormone therapy, worse ACH, CAL, PD, plaque or gingivitis, and any history of oral surgery or extraction due to gum disease. Follow-up time was similar in those who lost any teeth (5.09 years) and those who did not (5.06 years) ($p = 0.22$) (Table 1).

Oral clinical measures are also included in Table 1. The mean baseline 'worst ACH' site among all participants was 4.60 mm (± 1.5), with a significant difference ($p < 0.01$) between those experiencing subsequent tooth loss (5.10 ± 1.8) and those who did not (4.40 ± 1.4). The mean number of sites with 4 mm or more of bone loss was 2.7 with a range of zero to 31. CAL at worst site at baseline was significantly higher among those with incident tooth loss compared to no loss (6.4 ± 2.1 and 5.7 ± 1.8 , respectively; $p < 0.01$); as was PPD at worst site (with loss, 5.3 ± 1.6 vs. no loss, 4.8 ± 1.2 ; $p < 0.01$). Among all women, the mean proportion

of teeth with any plaque was 51.3% (range 0–100%) and mean gingivitis (gingival bleeding) was 33.5% (range 0–100%).

The 5-year cumulative incidence of any tooth loss was 293 in 1,021 participants (28.7 per hundred women) (Table 2). Of the 293 participants with tooth loss at follow-up, 175 (59.7%) had lost only one tooth, 67 (22.9%) had lost 2 teeth and 51 (17.4%) had lost 3 or more teeth. Among participants losing teeth, an average loss of 1.85 teeth per person (SD = 1.63, range 1–14) occurred. One participant who lost all their teeth during the study period (7 teeth lost out of 7 at baseline). The main reason reported for tooth loss during follow-up caries (64.4%), followed by periodontal disease (13.6%). Other reasons given for incident tooth loss are reported in table 2.

Results from the logistic regression analyses are shown in Table 3. Each of the 3 clinical measures (ACH, CAL, PPD) were significant risk factors for incident tooth loss. Other variables that were also statistically significant risk factors of tooth loss in the multivariable adjusted analyses included diabetes history, prior gum disease/surgery, ever smoking, number of teeth lost at baseline, BMI and mean plaque index. The OR estimates for the non-clinical factors (in addition to each of the 3 clinical measures) across the three models were all very similar. Each of the models showed the greatest contribution to risk of tooth loss coming from diabetes history with about a 2.5 fold increase in risk. Surgery or extraction due to gum disease was associated with a 55% to 64% increased risk in the clinical models.

In the ACH multivariable adjusted model, each additional 1mm of ACH at baseline was associated with a 22% increase in risk for tooth loss. Similar findings were found in the PPD and CAL models. In the CAL model, each 1 mm worse attachment loss was associated with a 13% increased risk in tooth loss, while each 1 mm worse pocket depth was associated with a 26% increased risk of tooth loss in the next 5 years. The community model that used information from self-reported questionnaires included diabetes history, prior gum disease/surgery, ever smoking, number of teeth lost at baseline and BMI as significant risk factors for incident tooth loss (Table 3).

Table 4 shows the multivariable adjusted results from subgroup analyses stratified on tooth loss history. At baseline, a total of 184 (18%) women had no missing teeth. Among these women, risk of incident tooth loss was significantly associated in a multivariable model including ever smoking, worst ACH and prior hormone therapy use. Among those beginning the study period with at least 1 prior tooth loss (n=837, 82%), risk of incident tooth loss during the follow-up period included diabetes history, prior gum disease/surgery, worst pocket depth, worst ACH, BMI, and number of teeth lost at baseline.

Discussion

In the current study we examined risk factors of incident tooth loss in a prospective cohort of postmenopausal women. The observed cumulative rate of person-level tooth loss of nearly 30% within a 5 year period is compatible with other published findings, underscoring the fact that tooth loss occurs frequently and affects a large number of people, including postmenopausal women (23,32–36).

Our study may be the first to evaluate three separate clinical measures in a series of multivariate models in one prospective cohort. In addition, this study was able to evaluate a non-clinical model that used information solely from questionnaire data in the same cohort. All 4 models yielded similar results in their ability to simultaneously assess the contributions from multiple factors towards risk of incident tooth loss in these postmenopausal women.

Although prior studies evaluating ACH, CAL and PPD in relation to tooth loss have been conducted and found positive associations (12,23,33), few if any have been able to evaluate the individual effect magnitude of these clinical measures in one cohort, and be able to assess the magnitude of other important factors that contribute to these models at the same time. In addition, some previous studies have been relatively small (33). In our study, a fourth non-clinical community model was evaluated in the same cohort and found similar strengths as the clinically based models. This non-clinical model is relevant and may prove useful in settings where no clinical measures are available or attainable. Even within clinical settings, not all measures (ACH, CAL, PPD) may be available in all patients. Therefore, the consistency of all 4 models in assessing risk of tooth loss makes these findings relevant to most dental practitioners.

In the three clinical models, a set of additional factors that were associated with risk of incident tooth loss included history of diabetes, prior gum disease/surgery, cigarette smoking, number of missing teeth at baseline examination, BMI, and plaque. In the community model, significant risk factors for incident tooth loss included diabetes history, prior gum disease/surgery, smoking, number of teeth missing at baseline and BMI. Many of these factors have been previously reported as individual risk factors for tooth loss. However, our study is one of the first to assess 4 multivariate models prospectively in a cohort of postmenopausal women. Factors that may be important in this group are likely different from those in younger populations and men.

Consistent with our findings, many of the additional risk factors we describe have been identified in other prospective studies (9,11–13,15,16,23,36–40). Factors such as diabetes (41–43) and higher BMI (44) were important risk factors for tooth loss. Other studies have found oral and other factors such as hormone use, smoking, diabetes, partial edentulism, gum disease/surgery, bone or attachment loss, probing depth and plaque, are related to subsequent tooth loss (4,5,45–53).

A retrospective study within the Framingham Heart Study supported our findings that estrogen use is protective against tooth loss (54), and four cross-sectional studies identified gender (female), years since menopause, smoking, socio-economic status and attachment loss to correlate with tooth loss (55–58). However, not all studies have found associations with these factors. A retrospective study of postmenopausal Japanese women did not find that estrogen use, years since menopause or BMI were associated with tooth loss (59). However, over half of this group had prior hysterectomy or oophorectomy; smokers, diabetics and past estrogen users were excluded, limiting comparability. Since our study was restricted to postmenopausal females, not all study findings could be compared. Other previous studies have included men, different age groups, other ethnic and racial groups and populations with notably different prevalence rates of other diseases. Our cohort was a relatively healthy and ambulatory group of women who had relatively good oral hygiene habits.

Interestingly, risk factors of incident tooth loss varied by prevalence of tooth loss at baseline enrollment. In analyses stratified on prevalence of tooth loss at baseline (Table 4), smoking status showed the most risk of tooth loss among women who had no tooth loss at baseline, along with ACH, while hormone therapy use was a significant protective factor in those women. Among women with prevalent tooth loss at baseline, history of diabetes emerged as the strongest risk factor for future tooth loss. However, oral health indicators (ACH, PPD, prior oral surgery), BMI, and number of previous teeth lost were also significantly associated with incident tooth loss. As an illustration in those without prevalent tooth loss at baseline, a non-smoking, postmenopausal woman with average ‘worst ACH’ (5 mm), having previously taken estrogen, would have a 14% chance of losing at least one tooth in

the next 5 years, while a smoker and non-estrogen user would have a 54% chance of tooth loss in this time period. In those with prevalent tooth loss at baseline, a non-diabetic, postmenopausal woman with a BMI (30 kg/m²), average levels of 'worst ACH' (5 mm), number of teeth currently lost (5), PPD (5 mm) and no prior gum surgery or tooth extraction due to gum disease would have a 30% probability of losing a tooth within 5 years. However, when a positive history of diabetes is included, the same individual would have an 51% chance of tooth loss. These data suggest there may be different etiologies at play for those experiencing tooth loss earlier in life as opposed to in later postmenopausal years. In addition, differences in risk were identified according to number of teeth lost at baseline. The women with 20 or fewer teeth present at baseline (n=191) lost an average of 1.04 teeth during follow-up, compared 0.41 teeth in those with 21 or more teeth at baseline (n=830). This finding supports the fact that prevalent tooth loss predicts future loss, even though those individuals have fewer teeth remaining to lose.

While these models will require validation to assess their predictive value in other cohorts, the following additional illustrations may be informative to future development of such predictive models for postmenopausal women. Using the ACH multivariate risk model as an example, the probability of tooth loss for a non-diabetic, non-smoking postmenopausal woman with a BMI (30 kg/m²), average levels of 'worst ACH' (5 mm), number of teeth currently lost (5), plaque index (50%), and no prior gum surgery or tooth extraction due to gum disease has a 25% probability of losing a tooth within 5 years. The results using the clinically derived CAL and PPD measures and same 'average' conditions are virtually the same, with probabilities of tooth loss between 21–24%. Using the community model, the same individual as previously described would have a 23% chance of tooth loss. By using the average of the highest (worst) quintile for each variable ACH (7 mm), CAL (7 mm), PPD (7 mm), number of teeth lost at baseline (14), and BMI (35 kg/m²), for a postmenopausal woman with diabetes, smoker, history of gum surgery or tooth extraction due to gum disease, and plaque index (90%), we calculate an 80–87% probability for the loss of at least one tooth in the next 5 years. The community model, which omits the clinical measures, gives a similar estimate for likelihood of tooth loss, 79%.

In considering these findings, some potential limitations should be acknowledged. Our participants were fairly homogeneous and our results may not be generalizable to other racial or SES groups, or to the U.S. population at large. We were unable to carefully examine differences by factors such as race, education, income, type of insurance or marital status. In many longitudinal studies, bias due to nonresponse may be of concern. However, within our study population we maintained follow-up with over 75% of participants (Figure 1), reducing the potential influence of non-response bias. Women, and those who are married, or with higher education or income, are more likely than men to seek dental care (60), especially if dental coverage is carried (61), which could lead to more extractions. However, we did not capture the type of clinical center where these women received treatment or the type of dental practitioners sought out, thus were unable to assess this potential predictor. Our participants did have a relatively high proportion indicating preventive care within the last 12 months. Studies that enroll participants from dental clinics alone could lead to biased interpretations related to reasons for tooth loss. However, we did not recruit from dental clinics or based on dental care, we enrolled women from the original Buffalo cohort of the WHI that was recruited from the western NY community using flyers and letters sent to households and through regional advertisement. In the original WHI enrollment there was no focus on dental outcomes. Also, the majority of tooth extractions in adults are typically due to periodontal disease or caries, and more often extractions are recommended by the dentist than requested by the patient (62–68).

Strengths of the study are its large sample size of community-dwelling, postmenopausal women. We maintained a high response rate throughout follow-up. The follow-up duration allowed for sufficient events to conduct some sub-group analyses. The examinations were done using standardized protocols and trained professionals, reducing potential for misclassification and some sources of bias. By assessing clinical and socio-demographic baseline exposures, including tooth loss, we were able to establish temporal associations.

We developed a series of clinical and questionnaire-based multivariate risk models for incident tooth loss in older women. This information may help to identify individuals at increased risk, where preventive strategies may be targeted.

Acknowledgments

Grant Support: This study was supported by funding from National Heart, Lung, and Blood Institute (NHLBI) contract N01WH32122, NIH/NIDCR grants 1R01-DE13505 and DE04898, and USARMC grant DAMD 17-96-1-6319. Mr. Bole is supported on NCI training grant R25CA113951.

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Figure 1.
Recruitment flowchart for prospective study of postmenopausal women and incident tooth loss

Table 1

Participant characteristics of postmenopausal women in osteoporosis prospective study at baseline enrollment overall, and by tooth loss status at 5-year follow-up

Baseline Measures	Total Sample (N=1021) n (%) Mean (SD)	Tooth Loss – Yes (N=293) n (%) Mean (SD)	Tooth Loss – No (N=728) n (%) Mean (SD)	P-Value (t-test or Chi Square)
Demographics				
Age at baseline visit (yrs)	65.88 (6.70)	66.74 (6.95)	65.53 (6.57)	0.01
Race (White)	1000 (97.9)	286 (97.6)	714 (98.1)	0.59
Education				
High school or less	212 (21.2)	65 (22.6)	147 (20.6)	0.73
College or higher	790 (78.8)	223 (77.4)	567 (79.4)	
Marital status				
Currently married or cohabitating	728 (71.3)	216 (73.7)	512 (70.3)	0.21
Other	293 (28.7)	77 (26.3)	216 (29.7)	
Total family income last year				
Less than \$19,999	127 (13.1)	42 (15.1)	85 (12.3)	0.22
\$20–44,999	451 (46.5)	142 (51.0)	309 (44.7)	
\$50 or more	391 (40.4)	94 (33.9)	297 (43.0)	
Lifestyle				
Ever smoke cigarettes (yes)	469 (45.9)	158 (53.9)	311 (42.7)	0.001
Brush Teeth				
1× or less per day	234 (22.9)	78 (26.6)	156 (21.4)	0.07
2× or more per day	788 (77.1)	215 (73.4)	572 (78.6)	
Floss Teeth				
Not every week	181 (17.8)	59 (20.3)	122 (16.8)	0.18
1× per week	93 (9.2)	20 (6.9)	73 (10.1)	
More than 1× per week	293 (28.9)	77 (26.6)	216 (29.8)	
Every day	448 (44.1)	134 (46.2)	314 (43.3)	
Visit Dentist				
Once per year or more	939 (92.0)	261 (89.1)	678 (93.1)	0.03
Only with problem or never	82 (8.0)	32 (10.9)	50 (6.9)	
Health				
BMI (kg/m ²)	26.57 (5.12)	27.44 (5.60)	26.23 (4.88)	0.001
Diabetes history (yes)	43 (4.2)	22 (7.5)	21 (2.9)	<0.01
Years past menopause without hormone therapy	12.35 (9.75)	13.12 (9.92)	12.02 (9.66)	0.11
Current hormone therapy (yes)	491 (48.1)	121 (41.3)	370 (50.8)	0.01
Current HT or bone drug use (yes)	552 (54.1)	142 (48.5)	410 (56.3)	0.23
Worst T-score				
Normal, T=>-1.0	173 (16.9)	42 (14.3)	131 (18.0)	0.30
Osteopenia, -2.5<T<-1.0	469 (45.9)	143 (48.8)	326 (44.8)	

Baseline Measures	Total Sample (N=1021) n (%) Mean (SD)	Tooth Loss – Yes (N=293) n (%) Mean (SD)	Tooth Loss – No (N=728) n (%) Mean (SD)	P-Value (t- test or Chi Square)
Osteoporosis, T=<-2.5	379 (37.1)	108 (36.9)	271 (37.2)	
Oral Health				
Tooth loss (yes)	837 (82.0)	256 (87.4)	581 (79.8)	<0.01
Mean number of teeth	23.5 (5.21)	22.3 (5.42)	23.9 (5.05)	<0.001
Whole mouth mean alveolar crestal height (ACH) (mm)	2.44 (0.76)	2.67 (0.83)	2.35 (0.71)	<0.01
Worst ACH site (mm)	4.60 (1.54)	5.10 (1.77)	4.40 (1.39)	<0.01
Mean clinical attachment loss (CAL) (mm)	2.27 (0.64)	2.40 (0.7)	2.21 (0.6)	<0.01
Worst CAL (mm)	5.91 (1.89)	6.40 (2.06)	5.71 (1.78)	<0.01
Mean Pocket Depth (PPD) (mm)	1.93 (0.35)	1.99 (0.4)	1.91 (0.3)	<0.01
Worst PPD (mm)	4.94 (1.37)	5.30 (1.58)	4.79 (1.24)	<0.01
Oral surgery or extraction due to gum disease				
Ever	236 (23.8)	97 (34.5)	139 (19.6)	<0.01
Never	754 (76.2)	184 (65.5)	570 (80.4)	
Mean Plaque Index (%)	51.27 (24.7)	55.75 (25.3)	49.48 (24.3)	<0.01
Mean Gingival Bleeding (%)	33.51 (22.4)	36.07 (25.8)	32.48 (20.9)	0.02
Mean Calculus Index	0.63 (0.57)	0.69 (0.6)	0.60 (0.6)	0.03
Number of sites with 4 mm or more	2.67 (4.14)	3.64 (4.81)	2.28 (3.78)	<0.01
Follow-up Measures				
Mean number of teeth at follow- up	22.92 (5.55)	20.41 (5.93)	23.9 (5.05)	<0.01
Follow-up time (years)	5.07 (0.38)	5.09 (0.41)	5.06 (0.37)	0.22

* Percentages out of valid responses; Total Missing: Education=19, Income=52, Flossing=6, Oral Surgery=31; there were no significant differences of percentage Total Missing between the two groups

Table 2

Distribution of tooth loss, reported reasons for loss, and time to follow-up from baseline among postmenopausal women during 5-year follow-up

Number of teeth lost	Total participants n (%)	Reasons for tooth loss	Total number of teeth lost = 323 n (%) [†]
1	175 (59.7)	Caries	209 (64.7)
2	67 (22.9)	Periodontal disease	44 (13.6)
3	25 (8.5)	Retained root	23 (7.1)
4	10 (3.4)	Root canal	19 (5.9)
5	4 (1.4)	Fracture/accident	11 (3.4)
6	4 (1.4)	Implant	9 (2.8)
7	3 (1.0)	Ortho/malposed	6 (1.9)
8	1 (0.3)	Unable to determine	2 (<1.0)
10	3 (1.0)		
14	1 (0.3)		
Total with any tooth loss	323 in 293 women		

[†] Participants who lost more than one tooth may report more than one reason for the losses – percentages out of total teeth lost (n=323) by entire group.

Table 3

Multivariate logistic regression models for assessing risk of tooth loss among postmenopausal women

Included in analyses n=981	Odds Ratio Point Estimate	95% CI Lower Limit	95% CI Upper Limit	P-value
ACH Model				
Worst ACH (per mm)	1.22	1.11	1.35	<0.001
Diabetes history (yes)	2.52	1.28	4.95	0.007
Gum disease/surgery (yes)	1.56	1.10	2.19	0.012
Ever smoke (yes)	1.40	1.05	1.88	0.024
Teeth lost at baseline (per tooth)	1.03	1.00	1.06	0.030
BMI (per 5 kg/m² increase)	1.16	1.01	1.34	0.036
Mean plaque index (per 10% increase)	1.08	1.02	1.15	0.009
CAL Model				
Worst CAL (per mm)	1.13	1.05	1.23	0.002
Diabetes history (yes)	2.40	1.23	4.70	0.011
Gum disease/surgery (yes)	1.64	1.17	2.31	0.004
Ever smoke (yes)	1.43	1.06	1.91	0.018
Teeth lost at baseline (per tooth)	1.04	1.01	1.07	0.010
BMI (per 5 kg/m² increase)	1.16	1.01	1.34	0.037
Mean plaque index (per 10% increase)	1.07	1.01	1.15	0.018
PPD Model				
Worst PPD (per mm)	1.26	1.13	1.41	<0.001
Diabetes history (yes)	2.48	1.27	4.86	0.008
Gum disease/surgery (yes)	1.62	1.16	2.27	0.005
Ever smoke (y/n)	1.39	1.03	1.86	0.030
Teeth lost at baseline (per tooth)	1.05	1.02	1.08	<0.001
BMI (per 5 kg/m² increase)	1.14	1.00	1.31	0.070
Mean plaque index (per 10% increase)	1.07	1.00	1.14	0.036
Community Model(n=990)				
Diabetes history (yes)	2.45	1.26	4.77	0.008
Gum disease/surgery (yes)	1.97	1.43	2.70	<0.001
Ever smoke (yes)	1.42	1.06	1.89	0.018
Teeth lost at baseline (per tooth)	1.05	1.02	1.08	<0.001
BMI (per 5 kg/m² increase)	1.15	1.01	1.33	0.038

Table 4

Multivariable logistic regression estimates for assessing risk of tooth loss in postmenopausal women according to tooth loss at baseline

	Odds Ratio Point Estimate	95% CI Lower Limit	95% CI Upper Limit	P-value
<u>No Missing Teeth at Baseline</u> n = 184				
Ever smoke (yes)	2.40	1.08	5.33	0.032
Worst ACH (per mm)	1.64	1.20	2.24	0.002
Hormone therapy ever (yes)	0.34	0.15	0.79	0.012
<u>Any Missing Teeth at Baseline</u> n = 837				
Diabetes history (yes)	2.45	1.22	4.94	0.012
Gum disease/surgery (yes)	1.52	1.05	2.20	0.025
Worst PPD (per mm)	1.22	1.08	1.38	0.001
Worst ACH (per mm)	1.13	1.01	1.26	0.031
BMI (per 5 kg/m²)	1.28	1.10	1.47	0.002
Teeth lost at baseline (per tooth)	1.04	1.01	1.07	0.008