Predictors of Tooth Loss in Two US Adult Populations

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Abstract

Objectives: *This study determines tooth loss rate over a 10-year period and identifies predictors of tooth loss in two separate US adult longitudinal study populations.* ***Methods:*** *Subjects from the Baltimore Longitudinal Study of Aging (BLSA), consisting of 47 men and 47 women, ages ranging from 30 to 69 years, were compared to subjects from the VA Dental Longitudinal Study (VADLS) in Boston, MA, consisting of 481 men in the same age range. Baseline and follow-up examinations were performed on each cohort over a 10-year period. Using multivariate regression models, significant predictors of tooth loss were identified.* ***Results:*** *A mean rate of tooth loss of 1.5 teeth lost per 10 years was noted in the VADLS cohort compared to 0.6 teeth lost per 10 years in the BLSA (P<.001). Combining subjects from both populations, significant predictors of tooth loss were baseline values of: percent of teeth with restorations, mean probing pocket depth score, age, tobacco use, alcohol consumption, number of teeth present, and male sex. However, the set of significant predictor variables differed between the two populations and sexes. In BLSA men, number of teeth present, percent of teeth with restorations, mean probing pocket depth score, and alcohol consumption, but not age, were significant, while in BLSA women, only age was a significant predictor.* ***Conclusions:*** *Over a 10-year period, the incidence of tooth loss, the rates of tooth loss, and the predictors of tooth loss were found to vary by population and by sex. These results illustrate the limits of generalizing tooth loss findings across different study cohorts and indicate that there may exist important differences in risk factors for tooth loss among US adult populations. [J Public Health Dent 2004;64(1):31-37]*

Key Words: tooth loss, epidemiology, aging, dental caries, periodontal disease, longitudinal studies, cohort studies.

Tooth loss, or dental "mortality," is recognized as the final outcome of a multifactorial process that involves disease-related factors as well as health behaviors, patient preferences, and professional interventions. Tooth loss compromises the integrity of the dentition and can lead to clinically significant deficits in masticatory function and nutrition (1). While tooth retention in the United States has improved vastly over the last few decades, there are still many Americans affected by dental and oral diseases. In 1988–91, 10.5 percent of adults in the United States were edentulous, with the highest prevalence among those aged 75 years and older (43.9%) (2).

Many factors are associated with risk of tooth loss. Existing data suggest that the strongest predictor of individual tooth loss in US adults is dental caries, not periodontal disease (3-6). In an earlier report from the VA Dental Longitudinal Study analyzing the reasons of 1,142 extractions, it was found that 33.3 percent were extracted due to caries and only 18.7 percent due to periodontal disease (6). A longitudinal study conducted by Machtei et al. (7) on predictive factors for periodontal disease and tooth loss concluded that 64.1 percent of all teeth were extracted for reasons other than periodontal disease. In addition, while periodontal status may be an important predictor of tooth loss, it also has been shown that decrements in skeletal bone mineral density affect periodontal bone and that such systemic factors may increase the risk of tooth loss (8).

Interestingly, the role of age remains controversial and conflicting data exist regarding age as a risk factor for tooth loss (9-12). This may in part be due to the need to make a distinction between risk factors for loss of individual teeth from risk factors for loss of all teeth present. In studies on complete tooth loss (full edentulism), it is evident that age and number of teeth present are inversely correlated, but it remains unclear whether complete tooth loss is related to aging or to other risk factors. Rather, it appears that a better predictor of tooth loss than age is the number of teeth present at baseline (2,9,10). Others who have analyzed individual tooth loss, as compared to full edentulism, have not found a significant relationship between age and the incidence of tooth loss (11,12).

Another possible risk factor for tooth loss is a person's sex. Regarding individual tooth loss, White et al. (13) concluded that women were more likely to lose teeth than were men, across multiple age cohorts except those 65 and older. Hand et al. (11), in a cohort aged 65 years and older, also found that older men experience a significantly higher incidence of individual tooth loss than women. Several

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studies examining total tooth loss have concluded that sex plays no significant role in prediction of tooth loss (2,9,10,14).

Several longitudinal studies have examined tobacco use as a predictor of tooth loss. Krall et al. (15) reported that cigarette smokers had a threefold increased risk of tooth loss compared to nonsmokers. In a separate study, Krall et al. (16) also noted an increase in risk of tooth loss among pipe and cigar smokers. Burt et al. (12) reported that 71 percent of edentulous persons smoke, compared to 36 percent of dentate persons, but found that tobacco use was not significant in multivariate models predicting tooth loss. Eklund et al. (9) found tobacco use to be only a weak predictor of tooth loss.

Other factors studied as predictors of tooth loss include race, income level, and education level. Recent studies show tooth loss is more prevalent among blacks than whites, although the association appears to be in large part accounted for by differences in socioeconomic factors (3,14). In past studies, an inverse correlation was documented between tooth loss and education level and between tooth loss and income level (14).

The research literature on tooth loss has given much attention to reporting prevalence of complete edentulism and the mean number of missing teeth in various populations (2,10,13,14). The rate of edentulism is clearly an important indicator of a population's oral health status. Unfortunately, it dichotomizes populations into two overly broad categories, i.e., persons with at least one tooth remaining and those without any teeth, and is also an infrequent outcome in longitudinal studies. In contrast, tooth loss is a discrete and well-defined outcome for use in longitudinal studies. As the annual incidence of tooth loss in most US populations appears to be relatively low, adequate follow-up times of a decade or more may be needed for carrying out such studies. In part because of such limitations, few studies have prospectively documented rates of tooth loss (3,11,17).

Our aim was to determine the incidence of tooth loss and to identify the predictors of tooth loss, using two different urban populations over a 10-year longitudinal study period. We used two cohorts where subjects had similar comprehensive health status data available for the same 10-year observational period: the Baltimore Longitudinal Study of Aging (BLSA) in Baltimore, MD, and the Veterans Affairs Dental Longitudinal Study (VADLS) in Boston, MA.

Methods

Study Populations. *Baltimore Longitudinal Study of Aging (BLSA).* The subjects participating in this study were volunteer participants in the oral physiology component of the Baltimore Longitudinal Study of Aging (BLSA) (18,19). The participants were community-dwelling, ambulatory, white adults of middle socioeconomic status. The subjects were highly motivated, health conscious, and medically well characterized. They ranged in age from the mid-20s to mid-90s. The majority of the participants resided in the Baltimore-Washington metropolitan areas. Subjects were seen biennially and underwent a thorough dental, medical, biochemical, behavioral, and psychological evaluation.

Veterans Affairs Normative Aging and Dental Longitudinal Studies. The VA Normative Aging Study (VANAS) is a closed-panel prospective study of aging that began in 1963 and is still ongoing (20). At the study baseline, the VANAS enrolled 2,280 men between the ages of 21 and 84 years who were free of chronic medical disease and lived in the greater Boston metropolitan area. Participants returned to the study site approximately every three years, at which time they received comprehensive clinical examinations and completed questionnaires. In 1968, a total of 1,231 VANAS participants also volunteered to enroll in the VA Dental Longitudinal Study (VADLS) (21). The VADLS subjects received a comprehensive oral examination and completed oral health questionnaires every three years. The mean age of participants at the VADLS base-

TABLE 1
Subject Characteristics at Initial Examination

		BLSA		
	VADLS	Total	Men	Women
Number of subjects	481	94	47	47
Age (years)*	55.2±7.6	52.6±13.4	54.2±12.8	51.0±13.8
Tobacco use				
None	72%	79%	77%	81%
<1 pack cigarettes/day	8%	5%	4%	6%
≥1 pack cigarettes/day	7%	13%	13%	13%
Cigar/pipe/other	13%	3%	6%	0%
% drink 2 or more alcoholic drinks/day	21%	16%	26%	6%
Total number of teeth	22.0±5.2	25.2±3.9	24.9±3.7	25.3±4.2
Number of sound teeth†	7.9±4.5	9.7±5.5	10.1±5.3	9.3±5.6
Number of teeth with caries (with or without restorations)	3.9±3.4	1.2±1.5	1.0±1.2	1.4±1.7
Number of teeth with restorations (with or without caries)	13.8±4.8	14.2±4.9	13.9±4.5	14.5±5.3
Average probing pocket depth score on index teeth‡	0.6±0.6	0.7±0.4	0.7±0.5	0.6±0.4
Number of index teeth with probing pocket depth ≥5 mm	0.3±0.7	0.2±0.4	0.2±0.4	0.2±0.3
Average gingival index on index teeth‡	1.7±1.0	1.8±0.3	1.9±0.3	1.8±0.4
Number of index teeth with bleeding on probing	2.3±1.7	1.3±1.0	1.2±1.0	1.4±1.1

*Mean (± SD) unless indicated otherwise.
†No caries or restorations on any surface.
‡Measured on ordinal scale; values range from 0 to 3.
¶VADLS=VA Dental Longitudinal Study. BLSA=Baltimore Longitudinal Study of Aging.

line was 41±8 years, and in 1999 was 73±7 years (range=54 to 97 years). All VADLS subjects are men. While the majority of the participants were veterans, they were not patients of the VA health care system and received their medical as well as dental care from private health care providers (20).

Data Collection. Existing data from comprehensive oral examinations and histories were obtained from each study population. The criteria for assessments of DMF (decayed, missing, or filled) teeth and surfaces, and for periodontal status measures, were similar in both populations and were described by Baum (18) for the BLSA and by Kapur et al. (21) for the VADLS. Third molars and radiographically diagnosed caries were not included in our analyses of either data set.

The subjects in the BLSA study were those who were presented for examinations at both the 1978–80 and 1987–91 periods, and who were dentate at the initial examination. The 1978–80 cohort consisted of 360 subjects and the 1987–91 group consisted of 300 subjects. There were 94 subjects who had complete data for each of those BLSA time points. Periodontal probing pocket depths and gingival assessments were obtained on six index teeth (numbers 3, 9, 12, 19, 25, and 28). Pocket depth was measured at mesial and buccal sites and the deepest site per tooth was used in the analysis. The tooth loss rate was statistically normalized to a 10-year period. The analysis group consisted of 47 male and 47 female subjects (Table 1).

The subjects from the VADLS cohort were selected to correspond to the BLSA subject characteristics with regard to age, race, and examination dates. A total of 481 VADLS men had a dental study examination between 1978 and 1980, at which time they were dentate, and also had a follow-up examination between 1987 and 1991. At the initial examination, these subjects had 6 or more teeth present and were between the ages of 25 and 75 years. At each examination, a single calibrated dentist examiner counted all teeth present and recorded caries (primary and secondary) and restorations on all surfaces. Probing pocket depths and gingival assessments were obtained on all teeth, but only the index teeth used by the BLSA were used in these analyses. Pocket depths were measured at multiple sites per tooth, and the deepest site was recorded using an ordinal scale of 0 (≤2 mm) to 3 (≥5 mm). The Cornell Medical Index assessed alcohol consumption; tobacco smoking status was obtained by questionnaire (22). The mean length of time between examinations was 9.9 years.

A tooth was considered sound if all surfaces were free of clinical caries and free of restorations. A tooth was considered caries free if no caries was noted irrespective of the presence of restorations. Third molars were excluded from all tooth counts. The number of teeth lost between examinations was standardized to a 10-year follow-up period. Smoking status was dichotomized into nonsmoker or smoker of any type of tobacco.

Statistical Analysis. Statistical analyses were performed with the SAS system for Windows (23). Spearman correlation coefficients were computed for tooth loss rate and for each of the potential predictors: age in 1978–80 (baseline), initial number of teeth, number or percentage of teeth with restorations, number or percentage of teeth with caries, mean probing pocket depth score, mean gingival index score, alcohol use, smoking status, population (BLSA or VADLS), and sex. Predictors of tooth loss were identified using generalized linear models (PROC GENMOD), which assumed a Poisson distribution for the dependent variable, i.e., tooth loss rate. Independent variables included in the model were the predictor variables listed above and seven interaction terms (population × baseline age, population × restored teeth, population × carious teeth, population × mean probing pocket depth score, population × mean gingival index, population × alcohol use, and population × smoking status). To identify the most important predictors of tooth loss rate, those variables with the smallest chi-square value were removed sequentially until all remaining variables in the model were significant at $P<.10$.

TABLE 2.
Rates of Tooth Loss in VADLS and BLSA Populations

		BLSA		
	VADLS	Total	Men	Women
Number of subjects	481	94	47	47
Mean (±SD) number of teeth lost per decade	1.5±2.8	0.6±1.8	1.0±2.4	0.1±0.5
Percent of population losing one or more teeth	48%	19%	30%	9%

Results

Subject characteristics at the initial visit are listed in Table 1. The mean number of teeth present and the total number of sound teeth were somewhat lower in the VADLS group than in their BLSA counterpart. Additionally, the mean number of teeth with caries was thrice that of the BLSA cohort. The periodontal status variables were generally similar between the two cohorts, except that the VADLS subjects had bleeding on probing on almost twice the number of index teeth as the BLSA subjects. The oral health status variables at the initial examination among the BLSA participants were generally similar for both men and women (Table 1).

We found a mean rate of tooth loss of 1.5 per decade for VADLS subjects, compared to 0.6 per decade for the BLSA (Table 2). In the VADLS population, 48 percent of subjects lost one or more teeth over 10 years, compared to only 19 percent of BLSA subjects. When the BLSA data were analyzed by sex, the rate of tooth loss was 10-fold higher in men: 1.0 tooth lost per decade in men and 0.1 tooth lost per decade in women. In the BLSA, 30 percent of the men lost one or more teeth over 10 years, as compared to only 9 percent of the women.

The rate of tooth loss was analyzed with respect to age, by cohort and sex (Figure 1, Table 3). We found that, for all age groups, the VADLS cohort had significantly more teeth lost per decade than the total BLSA cohort (Table 3). However, the data from the BLSA population indicated that the rate of tooth loss was significantly dependent on the subject's sex, with BLSA men having a higher incidence and a higher rate of tooth loss than BLSA women. In fact, the BLSA men, from age 41 to age 75, apparently had an age-dependent rate of tooth loss quite similar to that of the VADLS men (Figure 1).

In bivariate correlation analysis for the combined populations (N=576), the tooth loss rate was significantly correlated with initial number of teeth (r=–0.33, P<.001), number of carious teeth (r=+0.27, P<.001), pocket depth score (r=+0.26, P<.001), male sex (r=+0.21, P<.001), age (r=+0.20, P<.001), smoking status (r=+0.15, P<.01), gingival index score (r=+0.15, P<.01), and number of restored teeth (r=+0.09, P=.03).

Table 4 shows the results of the generalized linear models regression in the combined populations (N=576). The independent variables of probing pocket depth, smoking, age, restored teeth, initial number of teeth, alcohol consumption, and male sex were all found to be significantly related to tooth loss rate. BLSA status as well as one of the interaction terms (population × alcohol) were also significant, indicating that the predictors of tooth loss were dissimilar in the two populations.

We therefore proceeded to construct separate models for the VADLS and BLSA populations (Table 5). The predictor variables identified as significant were generally similar when comparing the VADLS to the total BLSA population, except for the inclusion of male sex and the absence of smoking status and age from the final BLSA model. The results were similar when smoking status was dichotomized into heavy cigarette users (≥1 pack per day) vs all others (nonsmoker, <1 pack/day, or other tobacco). While alcohol consumption remained a significant variable in the final models for both the VADLS and BLSA cohorts, the directionality of the relationship was different. In the VADLS, self-report of consumption of two or more alcoholic drinks per day was associated with increased tooth loss, while in the BLSA the same behavior was associated with decreased tooth loss. This difference also was apparent when the BLSA men were analyzed separately (Table 6). This relationship did not change when smoking status was forced back into the BLSA models.

In the BLSA population, there were important differences by sex (Table 6). Among women, only age was a significant predictor of tooth loss. In contrast, the BLSA were more similar to the VADLS men in the tooth loss predictors identified. However, some age-related trends in caries and restorations were different in the two populations. In the VADLS, the youngest age group had a higher percentage of teeth with caries (15±13% of teeth) or restorations (72±17% of teeth) than the oldest age group (10±9% carious teeth and 62±21% restored teeth). In contrast, in the BLSA there was no age-related trend in the percentage of carious teeth, and the youngest subjects had fewer teeth with restorations (44±16%) than older subjects (64±18%).

FIGURE 1
Scatter Plot of Age vs Number of Teeth Lost per Decade (Open circles are DLS men, closed circles are BLSA men, and open triangles are BLSA women. Slopes were calculated and lines fit using ordinary least squares regression.)

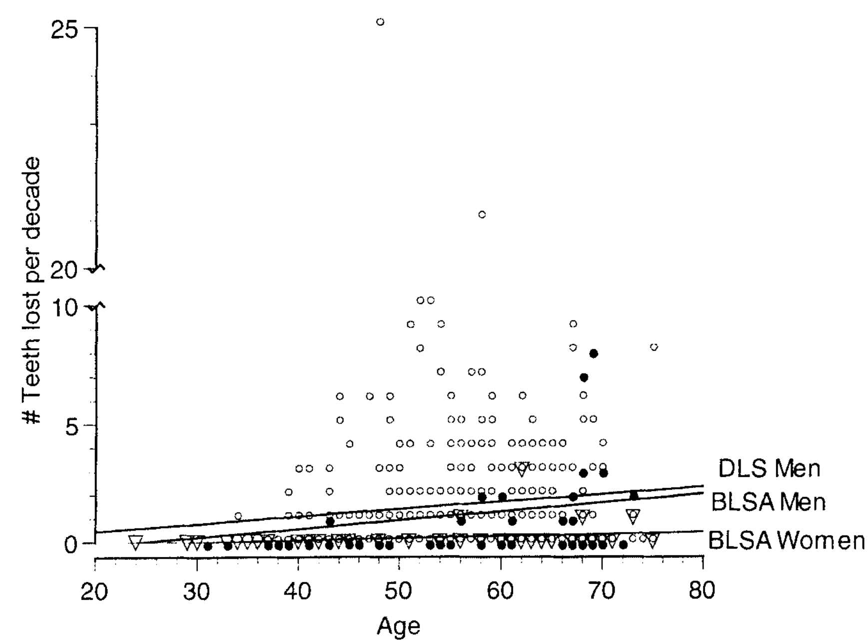

TABLE 3
Number of Teeth Lost per Decade by Age Group and Population

Age at Initial Examination (Years)	VADLS Mean ± SD	BLSA Total Mean ± SD	BLSA Men Mean ± SD	BLSA Women Mean ± SD
25–40	0.7±1.0 (n=12)	0±0 (n=23)	0±0 (n=9)	0±0 (n=14)
41–50	1.4±3.5 (n=114)	0.8±3.1 (n=17)	1.4±4.1 (n=10)	0±0 (n=7)
51–60	1.5±2.6 (n=239)	0.3±0.6 (n=22)	0.5±0.8 (n=10)	0.1±0.3 (n=12)
61–75	1.8±2.6 (n=116)	1.0±1.9 (n=32)	1.6±2.4 (n=18)	0.3±0.8 (n=14)

Discussion

The results from these analyses show a higher rate of tooth loss for the VADLS participants than the BLSA

TABLE 4
Results of Generalized Linear Models Regression in the Combined Populations (*N*=576) (Dependent variable is rate of tooth loss per decade. All independent variables are those measured at the initial examination.)

Independent Variable	Parameter Estimate	Standard Error	Chi-square	Pr>χ^2
Intercept	−2.3	0.6	14.9	.001
Mean pocket probing depth score	0.59	0.06	99.6	<.0001
Smoker	0.58	0.08	54.5	<.0001
Age	0.03	0.01	35.2	<.0001
% teeth with restorations	0.01	0.002	28.1	<.0001
DLS subject/drink 2+ alcoholic drinks/day (population × alcohol interaction)	1.59	0.31	25.6	<.0001
Initial number of teeth	−0.03	0.01	21.7	<.0001
Drink 2+ alcoholic drinks/day	−1.30	0.30	19.0	<.0001
BLSA population	−0.65	0.20	10.8	.001
Male sex	1.43	0.45	9.9	.002
Mean gingival index score	−0.04	0.05	1.6	.21

TABLE 5
Results of Generalized Linear Models Regression in the Separate VADLS and BLSA Populations (dependent variable=rate of tooth loss) (All independent variables are those measured at the initial examination.)

Independent Variable	Parameter Estimate	Standard Error	Chi-square	Pr>χ^2
VADLS				
Intercept	−1.30	0.37	12.6	.0004
Mean pocket probing depth score	0.63	0.05	161.9	<.0001
Smoker	0.56	0.08	48.5	<.0001
Age	0.03	0.01	26.5	<.0001
Initial number of teeth	−0.03	0.01	21.2	<.0001
% teeth with restorations	0.01	0.002	21.0	<.0001
Drink 2+ alcoholic drinks/day	0.29	0.10	8.9	.003
BLSA				
Intercept	−3.32	1.38	5.8	.02
% teeth with restorations	0.05	0.01	19.2	<.001
Male sex	1.82	0.52	12.1	<.001
Drink 2+ alcoholic drinks/day	−1.07	0.32	10.8	.001
Mean pocket probing depth score	0.91	0.31	8.5	.003
Initial number of teeth	−0.09	0.04	5.4	.02

participants over the 10-year period of observation. At the study baseline, the VADLS subjects had on average 12 percent fewer teeth present, 18 percent fewer sound teeth (i.e., teeth with neither caries nor restorations), and three times as many teeth with caries than the BLSA subjects. Such important differences between the two populations at their baselines may account in large part for the observed differences in tooth loss over time.

Particularly noteworthy was that even over a 10-year period, tooth loss was experienced by fewer than half of the study population. Overall, 57 percent of the subjects did not lose any teeth, which resulted in a skewed distribution of the dependent variable (number of teeth lost per decade). We thus specified a Poisson distribution when modeling the predictors of tooth loss with the generalized linear regression technique. In addition, only 18 BLSA subjects lost any teeth, resulting in limited power to detect significant predictors of tooth loss in that cohort. Still, the significant predictors of tooth loss that we identified are consistent with other findings, with the exception of the apparently "protective" effect noted of alcohol consumption in BLSA men.

Unfortunately, we were unable to further explore potential differences in risk factors for individual tooth loss as compared with total tooth loss. In the two populations we have considered here, there were only two subjects who lost all remaining teeth (both lost 15 teeth) during the specified time interval, and in one of these subjects the teeth were extracted in more than one stage. In contrast, 12 other individuals lost 10 or more teeth over the time interval without becoming completely edentate. Due to the low number of subjects becoming fully edentulous, we were unable to investigate any possible differences between loss of any teeth and loss of all remaining teeth.

The higher rate of tooth loss among the VADLS as compared to the BLSA may also be related to socioeconomic factors. Differences in education and available income for dental services may in part explain the higher rate of tooth loss in the VADLS. The participants from the BLSA were more highly educated (an average of 4 years of education beyond high school) and have the available income for dental services (18,19). Such an interpretation would be consistent with the findings of Eklund and Burt (9) from their longitudinal analysis of US national population data. They noted lower economic and educational strata were significantly associated with total tooth loss. We examined the impact of including socioeconomic status (SES) data in the model for the VADLS population. In the generalized regression model, the SES term was not significant (B=−0.004+0.024, *P*=.64). Furthermore, forcing SES into the model did not change the contribution of other variables that may be related to SES. For example, the regression coef-

TABLE 6
Results of Generalized Linear Models Regression in BLSA Population, by Sex (dependent variable=rate of tooth loss) (All independent variables are those measured at the initial examination.)

Independent Variable	Parameter Estimate	Standard Error	Chi-square	$Pr>\chi^2$
BLSA men				
Intercept	–0.53	1.17	0.2	0.55
% teeth with restorations	0.07	0.01	21.5	<0.0001
Initial number of teeth	–0.19	0.05	13.7	0.0002
Mean pocket probing depth score	1.10	0.34	10.5	0.001
Drink 2+ alcoholic drinks/day	–0.73	0.35	4.4	0.04
BLSA women				
Intercept	–7.38	2.85	6.7	0.01
Age	0.09	0.04	4.2	0.04

ficients for initial number of teeth (*B=–0.03±0.007*), percentage of teeth with restorations (B=.01±0.002), and smoking status (B=0.58±0.08) were unchanged from those of the model without inclusion of the SES term.

We further explored the role of smoking various tobacco products on risk of tooth loss. In the analyses presented here, we defined smokers to include cigarette, cigar, or pipe users. However, in the BLSA, there were only three subjects who used cigars, so we could not feasibly model cigar smoking separately in that population. In contrast, in the VADLS population we were able to examine cigarette use separately and compare the results to smoking any tobacco. Not only were the regression coefficients for the smoking term almost identical in the two models, but regression coefficients for most other variables in the model were also minimally affected by the substitution.

The BLSA women had a dramatically lower rate of tooth loss compared to either the VADLS or BLSA men. Upon initial examination, the VADLS cohort exhibited twice the number of teeth lost per decade as the total BLSA population. However, the major source of this difference apparently was due to male sex. When examined separately, the BLSA men had a rate of tooth loss similar to that of the VADLS cohort. Others have noted this sex difference in tooth loss. Hunt et al. (4), in their five-year study of Iowa elders, found that women had a much lower rate of tooth loss than men (0.8 vs 1.4). The even larger difference that we found in tooth loss between BLSA women and VADLS and BLSA men occurred despite the fact that BLSA men and women had similar baseline values for most of the predictor variables analyzed. The sex differences may be attributed in part to behavioral factors influencing self-care and access to health care services. It thus becomes readily apparent that other factors will need to be identified and measured for inclusion in analytic models to account more fully for the observed variance in tooth loss. In our analyses using the combined populations, the final set of predictor variables accounted for, at most, 24 percent of the variance.

While great strides have been made in improving oral health and in educating the American public on the importance of tooth retention, tooth loss still remains highly prevalent in the United States. It is clear that risk factors for tooth loss in various populations need to be better characterized. Additional longitudinal studies may be needed to determine whether predictors of tooth loss are similar across other populations. Continued follow-up observation of established cohorts, such as those used in this study, may further serve to identify and characterize predictors of tooth loss. Furthermore, collection of dental utilization data may also serve to more fully explain the variance in rates of tooth loss in US populations.

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