Complete Edentulism Prior to the Age of 65 Years is Associated with All-Cause Mortality

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Abstract

Purpose: *We examine the relationship between complete edentulism prior to the age of 65 years and all-cause mortality after adjustment for socioeconomic characteristics.* ***Methods:*** *Using data from 41,000 adult participants in the 1986 National Health Interview Survey, with mortality follow-up data on each cohort member through December 31, 2002 (16 years follow-up), we estimated the relative odds of all-cause mortality among adults (age ≥18 years) with complete edentulism prior to the age of 65 years compared with that among those without the condition. Multivariable-adjusted logistic regression analyses were repeated for complete edentulism at any age.* ***Results:*** *The age-standardized prevalence of complete edentulism was 12.3 percent [95 percent confidence interval (CI), 12.0-12.6]. Among persons aged <65 years, the risk of death from all causes was 19 percent for persons with complete edentulism compared to 10 percent for persons without. Compared with those without complete tooth loss, the risk of death from all causes was 1.5 (95 percent CI, 1.3-1.7) (P < 0.001) times greater for persons with complete edentulism prior to the age of 65 years after multivariable adjustment. Similar results were observed for complete edentulism among persons aged ≥65 years.* ***Conclusions:*** *Complete edentulism prior to the age of 65 years was associated with all-cause mortality after multivariable adjustment for several socioeconomic characteristics. These results provide further evidence supporting the notion that poor oral health as evidenced by complete edentulism is an important public health issue across the lifespan.*

Key Words: tooth loss, mortality, cohort studies

Introduction

Poor oral health has been shown to have a negative effect on people's overall health and quality of life (1,2). Until fairly recently, tooth loss was considered a natural part of the aging process; however, advances in oral health have resulted in decreases in the prevalence of tooth loss in the United States since at least the 1950s (3-5). During 1999-2000, only about 8 percent of US adults were completely edentulous (<1 percent of those aged 20-39 years; 5 percent, 40-59 years; 25 percent, ≥60 years) (6), whereas in the late 1950s, more than half of US adults aged 65 years or older were edentulous (4 percent of those aged 25-34 years; 10 percent, 35-44 years; 22 percent, 45-54 years; 38 percent, 55-64 years; 54 percent, 65-74 years; 67 percent, ≥75 years) (7). Despite this decrease in the percentage of Americans with complete edentulism, the absence or loss of all natural teeth, edentulism remains an important public health problem both in the United States and worldwide (2).

Edentulism has been associated with an increased risk for systemic chronic disease and death (8-16). The increased death rate among people with tooth loss may in part be because tooth loss is a marker for underlying factors associated with death risk, including behavioral factors, socioeconomic factors, infection, and inflammation (17,18). However, the relationship between tooth loss and mortality independent of socioeconomic characteristics remains unclear (18,19). Moreover, because edentulism most often affects older persons, relationships between edentulism and mortality prior to the age of 65 years is not often considered. Using data from the 1986 National Health Interview Survey (NHIS), we examined the relationship between self-reported complete edentulism and risk for death (after adjusting for socioeconomic variables) among all adults aged ≥18 years and, separately, among those aged 18-64 years.

Methods

The NHIS is a cross-sectional household interview survey of the civilian, noninstitutionalized population of the United States. Data are collected through a personal household interview conducted by interviewers employed and trained by the US Bureau of the Census according to procedures specified by the National Center for Health Statistics. Data are collected from each of the 50 states and the District of Columbia with use of a multistage area probability sampling plan designed to obtain nationally representative estimates. A detailed description of the sampling plan for the 1986 NHIS is provided elsewhere (20), and a full description of the NHIS and its procedures can be obtained online at http://www.cdc.gov/nchs/nhis.

In 1986, the NHIS questionnaire consisted of basic health and demographic items and questions on

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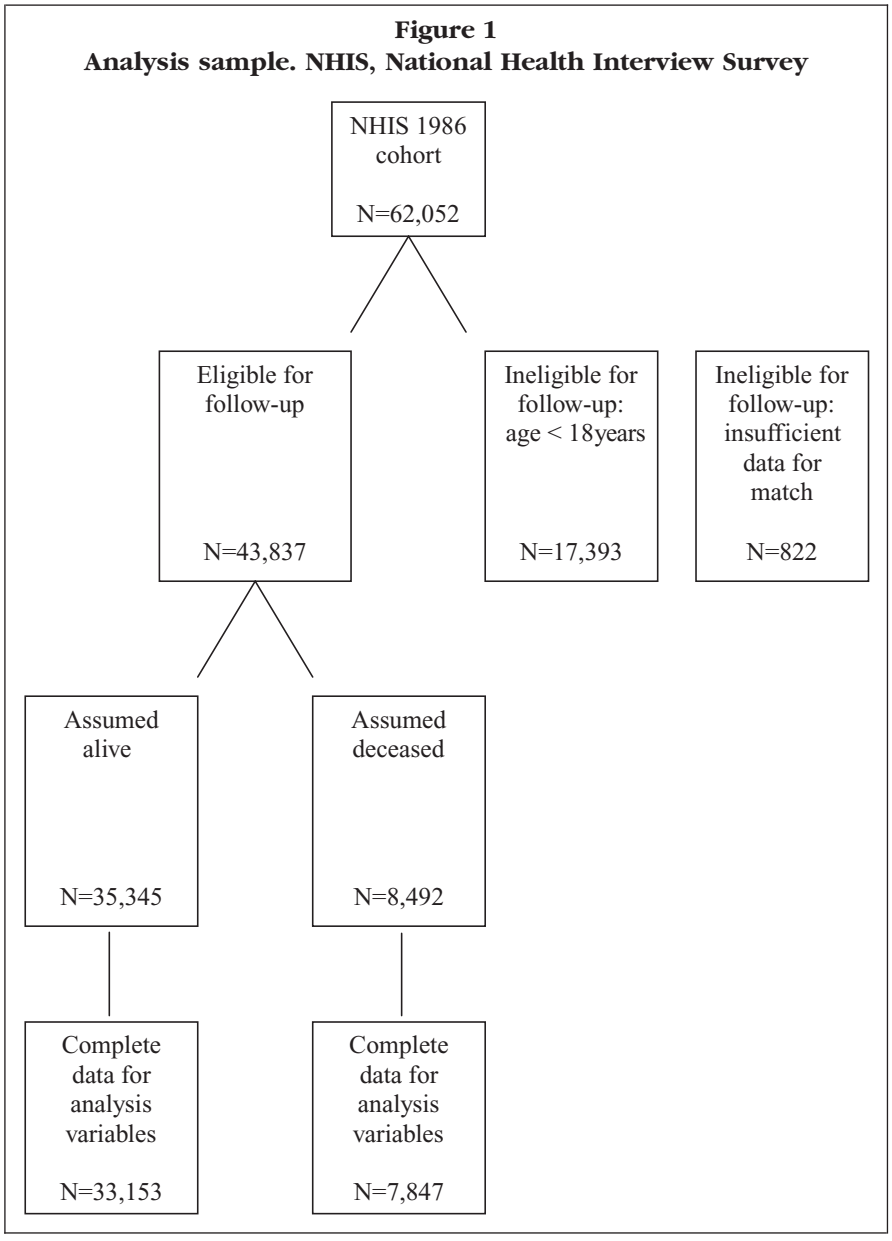
current health topics. Participants were asked about their health status, including any health conditions, their health-care utilization, and their health insurance. The 1986 NHIS questionnaire also included a dental health supplement, one question of which asked respondents whether they had lost all their teeth (i.e., whether they had complete edentulism). The validity of self-reported tooth loss compared with clinically derived measures has been examined (21-24) and shown to provide good to excellent estimates. For this analysis, early complete edentulism was defined as self-reported complete edentulism prior to the age of 65 years based on respondents' age at the time of the interview.

To ascertain the vital status of each cohort member through December 31, 2002 (approximately 16 years after the survey), we merged the 1986 NHIS data on survey participants aged 18 years or older at the time they participated in the survey with follow-up mortality data from the National Death Index (NDI), which has been shown to capture 93-98 percent of all US deaths (25-27). Deceased NHIS participants were matched to the NDI by social security number, first and last names, middle initial, race, sex, marital status, birth date (day, month, and year), state of birth, and residence. Eligible NHIS participants with a "true" NDI record match were assumed to be dead, and those with no NDI record match or an NDI record match considered to be "false" were assumed to be alive (28). Follow-up (i.e., survival) time was calculated as the difference between the 1986 NHIS baseline interview date and the last known date alive for NHIS participants listed as decedents in the NDI and as the difference between the interview date and December 31, 2002, for those not listed as decedents.

For this analysis, NHIS data and follow-up information were available for 41,000 1986 NHIS participants aged 18 years or older. Of the 62,052 NHIS participants interviewed in 1986, 43,837 were eligible for follow-up, 17,393 were ineligible because they were younger than 18 years old at the time of the interview, and 822 were ineligible because they had insufficient data for matching to the NDI (Figure 1). Of those eligible for follow-up, the NDI showed that 19 percent were deceased, and the other 81 percent were assumed to be alive. An additional 2,837 respondents (645 of whom died during follow-up) were excluded because of missing data for analysis variables, leaving exactly 41,000 of the NHIS respondents for analysis. Compared with survey participants included in the analysis, those who were excluded were more likely to be aged ≥65 years (21 percent versus 16 percent, $P \leq 0.05$), less likely to be White (82 percent versus 86 percent, $P \leq 0.05$), less likely to have at least 12 years of education (26 percent versus 24 percent, $P \leq 0.05$), and more likely to have an annual income below $20,000 (42 percent versus 38 percent, $P \leq 0.05$). The crude prevalence of complete edentulism (15 percent versus 10 percent, $P \leq 0.05$) and the percentage of participants who had died by the end of the follow-up period (22 percent

Figure 1
Analysis sample. NHIS, National Health Interview Survey



versus 19 percent, $P \leq 0.05$) were both slightly higher among those excluded from the analysis.

Cox proportional hazards regression was used to estimate, by means of the hazard ratio, the relative risk for death associated with early complete edentulism in age- and multivariable-adjusted analyses. Models were repeated for complete edentulism at any age. In addition to age, the multivariable models adjusted for sex, race (White, Black, other), education (<12 years, ≥12 years), family income (<$20,000, ≥$20,000, unknown), living situation (alone, with others), health insurance (yes, no), dental insurance (yes, no), body mass index [BMI: (weight in pounds × 704.5) ÷ (height in inches)^2], and the presence of specified conditions (activity limitation, arthritis, diabetes mellitus, hypertension, ischemic heart disease, cerebrovascular disease, lung cancer, any cancer other than lung cancer, asthma, chronic bronchitis, emphysema). Multivariable-adjusted models were repeated for cardiovascular disease (CVD) deaths identified by the *International Classification of Diseases*, Ninth revision, codes 390-459 for deaths occurring between 1986 and 1998 and by the *International Classification of Diseases*, Tenth revision, codes I00-I99 for deaths occurring between 1999 and 2002.

Analyses were conducted with the use of SAS v9.1.3 (2002-2003, SAS Institute, Cary, NC), and sample weights were used to make the NHIS representative of the civilian, non-institutionalized US population. SAS-callable SUDAAN v9.0.1 (2005, Research Triangle Institute, Research Triangle Park, NC, USA) was used to account for the NHIS' complex sampling design (which involved both clustering and stratification) and to obtain accurate variance estimates. We assessed the appropriateness of the proportional hazard assumption for the variables in our final model with log–log survival plots and Schoenfeld residual plots. Ordinary least squares regression was used to assess the relationship between residuals and follow-up time. We also fit the final model to the data in unweighted analyses using Stata v9.2 (2007, StataCorp, College Station, TX, USA) and examined the proportional hazard assumption using the Stata procedure STPHTEST. Without exception, all covariates in the final model satisfied the proportional hazard assumption. Model parameter estimates were computed by maximum likelihood techniques, and 95 percent confidence intervals (CIs) were based on the standard error of the model coefficients. All statistical inferences were based on a significance level of 0.05.

Results

Overall, 15 percent of the sample was aged 18-24 years; 43 percent, 25-44 years; 26 percent, 45-64 years; 5 percent, 65-69 years; 4 percent, 70-74 years; and 6 percent, ≥75 years. About half (47 percent) of the sample members were women, 86 percent were White, 11 percent were Black, and 3 percent were of another race. Twenty-four percent of the sample had less than a high school education, 38 percent reported a family income below $20,000, and 18 percent did not have Medicare or private insurance.

The estimated age-standardized prevalence of complete edentulism was 12.3 percent (95 percent CI, 12.0-12.6), including 6 percent among those aged 18-64 years, 30 percent among those aged 65-74 years, and 46 percent among those aged ≥75 years (Table 1). Other respondent characteristics associated with complete edentulism included being female ($P = 0.04$), having less education ($P < 0.001$), having lower family income ($P < 0.001$), lacking health insurance ($P < 0.001$) or dental insurance coverage ($P < 0.001$), being underweight, overweight, or obese (compared to normal weight) ($P < 0.001$), having activity limitation ($P < 0.001$), and presence of several chronic conditions (diabetes, ischemic heart disease, emphysema; all $P < 0.001$) (Table 1). Associations between complete edentulism and White race and prevalent hypertension or bronchitis were marginally significant ($P = 0.05$). For those without selected conditions, the prevalence of complete tooth loss was 13.2-13.7 percent (data not shown).

Among persons aged <65 years at their NHIS interview, 801 (2.2 percent) died within 5 years, 1,841 (5.1 percent) died within 10 years, and 3,471 (9.7 percent) died within the 16-year follow-up period. Death during follow-up also occurred among 2,251 (56.4 percent) of the participants aged 65-74 years and 2,125 (84.6 percent) of those aged ≥75 years.

In unadjusted analyses, complete edentulism prior to the age of 65 years was significantly associated with all-cause mortality (Figure 2; Table 2), as was complete edentulism among persons aged 65 years or older (Table 2). Among persons aged <65 years, the risk of death from all causes was 19 percent for persons with complete edentulism compared with 10 percent for persons without (Table 2). After multivariable adjustment for age, sex, race, education, income, living situation, insurance (Medicare or private, Medicaid, private dental), BMI, and comorbidity [activity limitation, arthritis, diabetes, ischemic heart disease, cerebrovascular disease, cancer (excluding lung), asthma, chronic bronchitis, emphysema, lung cancer], the risk of death from all causes was estimated to be 1.5 (95 percent CI, 1.3-1.7) ($P < 0.001$) times greater for persons with complete edentulism prior to the age of 65 years compared with those without.

Death from CVDs. Among persons aged <65 years in their NHIS interview, 259 (0.7 percent) died from CVD within 5 years, 607 (1.7 percent) died within 10 years, and 1,160 (3.2 percent) died within the 16-year follow-up period. Death from CVD during follow-up also occurred among 1,053 (26.2 percent) of the participants aged 65-74 years and 1,200 (47.3 percent) of those aged ≥75 years. Associations between complete edentulism and death from CVD was similar to that

Table 1
Prevalence and Adjusted Relative Odds of Complete Edentulism by Respondent Characteristics: National Health Interview Survey, 1986

	Complete edentulism	
	Prevalence (95% CI)*	aOR (95% CI)†
Overall	12.3 (12.0-12.6)	
Age (years)		
<65	6.3 (6.0-6.5)	1.0 (referent)
65-74	30.1 (28.7-31.6)	2.7 (2.4-3.1)
≥75	45.8 (43.8-47.8)	4.7 (4.1-5.4)
Sex		
Men	12.0 (11.6-12.5)	1.0 (referent)
Women	12.6 (12.1-13.0)	1.1 (1.0-1.2)
Race		
White	12.3 (12.0-12.6)	1.5 (1.0-2.1)
Black	13.3 (12.4-14.3)	0.9 (0.6-1.3)
Other	9.2 (7.5-11.3)	1.0 (referent)
Education		
<12 years	19.7 (19.0-20.4)	3.0 (2.7-3.3)
≥12 years	8.4 (8.1-8.8)	1.0 (referent)
Family income		
<$20,000	17.2 (16.6-17.8)	1.9 (1.7-2.1)
≥$20,000	8.1 (7.7-8.5)	1.0 (referent)
Unknown	11.3 (9.8-13.1)	1.6 (1.2-2.1)
Living situation		
Alone	13.3 (12.4-14.1)	1.0 (0.9-1.1)
With others	12.1 (11.7-12.5)	1.0 (referent)
Covered by Medicare or private health insurance		
Yes	11.7 (11.3-12.0)	1.3 (1.2-1.6)
No	17.4 (15.8-19.2)	1.0 (referent)
Received Medicaid benefit during past 12 months		
Yes	20.6 (18.8-22.6)	1.1 (0.9-1.3)
No	11.9 (11.6-12.3)	1.0 (referent)
Covered by private dental insurance		
Yes	8.8 (8.2-9.6)	0.8 (0.7-0.9)
No	13.6 (13.2-14.0)	1.0 (referent)
Body mass index (kg/m^2)		
<18.5	13.8 (12.3-15.4)	1.2 (1.0-1.4)
18.5-24.9	11.2 (10.7-11.6)	1.0 (referent)
25.0-29.9	12.4 (11.9-12.9)	1.2 (1.1-1.4)
≥30	15.5 (14.6-16.4)	1.5 (1.3-1.7)
Activity limitation		
Yes	17.2 (16.5-18.0)	1.5 (1.4-1.7)
No	10.7 (10.4-11.1)	1.0 (referent)
Prevalent conditions		
Arthritis	14.0 (9.6-20.0)	1.1 (0.6-2.1)
Diabetes mellitus	22.0 (19.0-25.2)	1.6 (1.4-2.0)
Hypertension	15.0 (13.7-16.3)	1.1 (1.0-1.3)
Ischemic heart disease	20.2 (16.2-24.9)	1.6 (1.3-1.9)
Cerebrovascular disease	20.7 (14.6-28.4)	1.2 (0.9-1.7)
Cancer (excluding lung)	12.5 (10.1-15.5)	1.0 (0.8-1.4)
Chronic bronchitis	18.8 (15.3-22.8)	1.3 (1.0-1.9)
Asthma	14.2 (11.7-17.1)	0.8 (0.6-1.1)
Emphysema	22.6 (16.5-26.1)	2.4 (1.8-3.3)
Lung cancer	19.5 (12.1-29.9)	1.6 (0.7-3.7)

* Age-standardized to the 2000 US standard population.
† Adjusted for all variables shown in the table.
aOR, adjusted relative odds; CI, confidence interval.

described above for all-cause mortality for both persons aged <65 years and those aged 65 years or older (Table 3).

Premature All-Cause Mortality. Of the 34,514 respondents aged 64 years or younger at interview, 1,872 died prior to the age of 65 years; these deaths constituted 54 percent (1,872/3,471) of all deaths among respondents in this age group over the 16-year follow-up period. The age-standardized risk of premature death (i.e., death prior to age 65) was 10 percent among respondents with early complete edentulism and 5 percent among those without. The relative risk of premature death among those with early complete edentulism compared with the risk among those without was 1.2 (95 percent CI, 1.0-1.5; $P = 0.05$) after adjustments for age, sex, race, education, income, living situation, insurance status, and the presence of comorbid conditions.

Secondary Analysis. Because it is difficult to postulate why tooth loss might be associated with external causes of death (e.g., unintentional injuries, suicides, homicides, legal intervention, complications of medical or surgical care) that are common among younger persons, multivariable-adjusted regression models were repeated after excluding death from such causes, and findings similar to those shown in Table 2 were observed.

Discussion

In this large, nationally representative sample of adults, we observed a statistically significant association between complete edentulism prior to the age of 65 years and risk for death during a 16-year follow-up period after adjusting for several sociodemographic variables. Associations were similar for persons aged 65 years or older. We also observed a marginally significant increased risk for premature death associated with early complete edentulism. And, similar to previous work examining associations between tooth loss and CVD (9,12,13,15), we observed modest associations

Figure 2
Crude survival estimates for adults who participated in the 1986 National Health Interview Survey by presence of self-reported complete edentulism prior to the age of 65 years and at any age

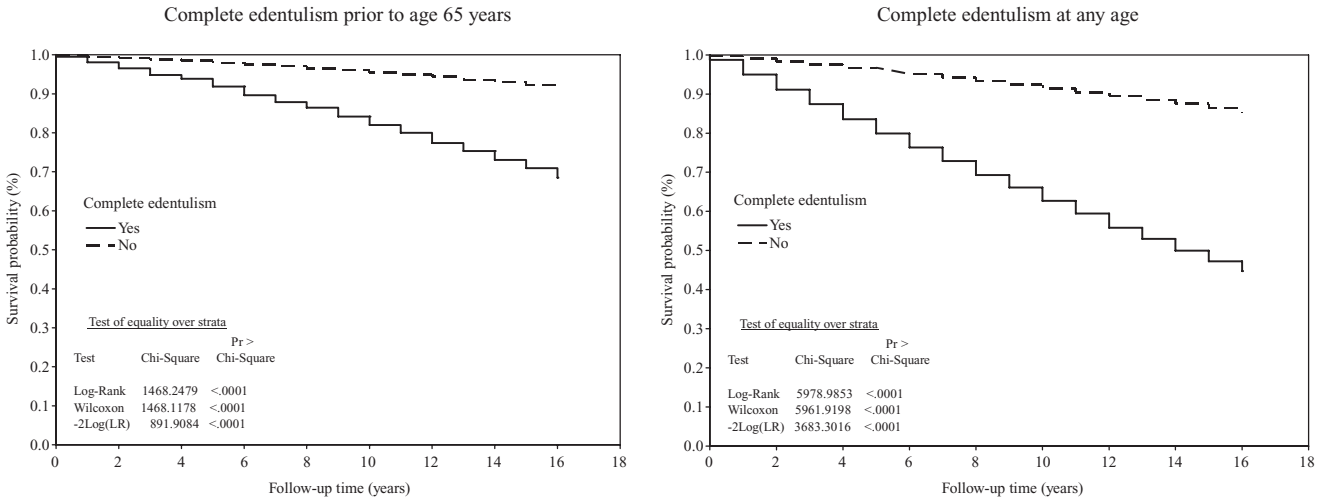


Table 2
Risk and Relative Risk for Death from All Causes Associated with Complete Edentulism Status by Age at Baseline Interview among 1986 NHIS Participants

Follow-up period		18-64 years	≥65 years
5 years from baseline	Risk for death* (complete versus no complete edentulism)	4.7% versus 2.1%	30.1% versus 22.4%
	Crude RR (95% CI)†	4.6 (3.9-5.5)	1.7 (1.5-1.9)
	Age-adjusted RR (95% CI)†	2.2 (1.9-2.7)	1.4 (1.3-1.6)
	Multivariable-adjusted RR (95% CI) †‡	1.5 (1.2-1.9)	1.3 (1.1-1.4)
10 years from baseline	Risk for death* (complete versus no complete edentulism)	10.7% versus 5.0%	53.9% versus 43.5%
	Crude RR (95% CI)†	4.5 (4.0-5.1)	1.6 (1.5-1.7)
	Age-adjusted RR (95% CI)†	2.1 (1.9-2.4)	1.4 (1.3-1.5)
	Multivariable-adjusted RR (95% CI) †‡	1.4 (1.2-1.7)	1.3 (1.1-1.4)
Overall, 16 years¶	Risk for death* (complete versus no complete edentulism)	19.1% versus 9.7%	76.5% versus 66.8%
	Crude RR (95% CI)†	4.4 (4.0-4.8)	1.6 (1.5-1.7)
	Age-adjusted RR (95% CI)†	2.0 (1.8-2.2)	1.4 (1.3-1.5)
	Multivariable-adjusted RR (95% CI) †‡	1.5 (1.3-1.7)	1.3 (1.2-1.4)

* Age-standardized to the 2000 US standard population.
† Relative risk comparing those with complete edentulism to those with no complete edentulism (referent).
‡ Adjusted for age, sex, race, education, family income, living situation, health insurance, dental insurance, body mass index, comorbidity [activity limitation, arthritis, diabetes, ischemic heart disease, cerebrovascular disease, cancer (excluding lung), asthma, chronic bronchitis, emphysema, lung cancer].
¶ Mortality status based on follow-up through December 31, 2002.
RR, relative risk; CI, confidence interval; NHIS, National Health Interview Survey.

between complete edentulism and CVD mortality among persons with edentulism prior to the age of 65 years as well as among older persons.

These findings complement those of other studies that were primarily focused on older populations. In a Danish community-based cohort of adults, Holm-Pedersen and colleagues (8) observed an association between edentulism at the age of 70 years and death over a 21-year follow-up period (hazard ratio, 1.26; 95 percent CI, 1.03-1.55). In a study of 75-year-old men and women residing in three Nordic countries, Osterberg and associates (29) observed significant relationships between the number of teeth remaining and death over a 7-year period of follow-up. In contrast, Tu and colleagues (19) did not observe a significant relationship between edentulism and death during more than 50 years of following the Glasgow alumni cohort of more than 12,000 men and women younger than 30 years at baseline. And, in a Japanese study of men and women aged 80 years or older, Morita and colleagues (30) found edentulism to be associated with death among men but not among women during 10 years of follow-up.

Table 3
Risk and Relative Risk for Death from Cardiovascular Disease Associated with Complete Edentulism Status by Age at Baseline Interview among 1986 NHIS Participants

Follow-up period		18-64 years	≥65 years
5 years from baseline	Risk for death* (complete versus no complete edentulism)	1.4% versus 0.7%	16.5% versus 11.3%
	Crude RR (95% CI)†	5.1 (3.8-6.8)	1.9 (1.6-2.2)
	Age-adjusted RR (95% CI)†	2.1 (1.5-2.8)	1.6 (1.4-1.8)
	Multivariable-adjusted RR (95% CI)†‡	1.4 (0.9-2.0)	1.3 (1.1-1.5)
10 years from baseline	Risk for death* (complete versus no complete edentulism)	3.6% versus 1.6%	28.6% versus 21.8%
	Crude RR (95% CI)†	4.9 (4.1-6.0)	1.7 (1.5-1.9)
	Age-adjusted RR (95% CI)†	2.1 (1.7-2.5)	1.5 (1.3-1.6)
	Multivariable-adjusted RR (95% CI)†‡	1.4 (1.1-1.8)	1.2 (1.1-1.4)
Overall, 16 years¶	Risk for death* (complete versus no complete edentulism)	6.1% versus 3.3%	39.9% versus 34.6%
	Crude RR (95% CI)†	4.6 (4.0-5.3)	1.6 (1.5-1.7)
	Age-adjusted RR (95% CI)†	1.9 (1.6-2.2)	1.4 (1.3-1.5)
	Multivariable-adjusted RR (95% CI)†‡	1.4 (1.1-1.7)	1.2 (1.1-1.3)

* Age-standardized to the 2000 US standard population.
† Relative risk comparing those with complete edentulism to those with no complete edentulism (referent).
‡ Adjusted for age, sex, race, education, family income, living situation, health insurance, dental insurance, body mass index, comorbidity [activity limitation, arthritis, diabetes, ischemic heart disease, cerebrovascular disease, cancer (excluding lung), asthma, chronic bronchitis, emphysema, lung cancer].
¶ Mortality status based on follow-up through December 31, 2002.
RR, relative risk; CI, confidence interval; NHIS, National Health Interview Survey.

The results of this analysis are subject to several limitations. The most important limitation is that the analysis did not control for exposure to cigarette smoking, a risk factor for adult periodontitis and tooth loss (31), because the 1986 NHIS did not collect information about smoking. We attempted to address this challenge by controlling for the presence of several smoking-related conditions (e.g., emphysema, lung cancer, ischemic heart disease). Such use of smoking-related conditions as a proxy for smoking undoubtedly underestimates smoking exposure and is skewed toward cases with more chronic forms of disease (i.e., length-biased sampling). As a result, we may have overestimated the relationship between early complete edentulism and death. Information on diet or poor diet, a risk factor for tooth loss (32), was not available. Also, data used in the analysis, in particular the exposure variable (complete edentulism status), were based on self-report in 1986 only; some NHIS respondents may have become completely edentulous during follow-up and this would not be reflected in the exposure variable. Similarly, information was not available on changes in measures of confounding variables used in the multivariable-adjusted models. Finally, because the 1986 NHIS data did not indicate whether respondents suffered from partial edentulism, we were unable to examine associations between partial edentulism and death.

In summary, the results of this analysis showed that complete edentulism prior to the age of 65 years among US adults is associated with an increased risk for death, and thus provides further evidence supporting the notion that poor oral health is an important public health issue. Edentulism reflects a complex pattern of environmental, pathogenic, and socioeconomic conditions (33,34). Although poor oral health disproportionately affects older adults and disadvantaged, vulnerable populations, Americans of all ages and sociodemographic strata are subject to oral health threats. Therefore, health policies might be reoriented to incorporate oral health into general health-promotion strategies (35). In addition, efforts to control oral disease and associated illness might include the provision of primary oral health care in areas where these services are lacking and a continued effort to translate existing knowledge into cost-effective oral health programs (36).

References

1. World Health Organization. The world oral health report 2003. Geneva: WHO Press; 2003.
2. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. Bull World Health Organ. 2005; 83:661-9.
3. Eklund SA. Changing treatment patterns. J Am Dent Assoc. 1999;130:1707-12.
4. White BA, Caplan DJ, Weintraub JA. A quarter century of changes in oral health in the United States. J Dent Educ. 1995; 59:19-57.
5. Caplan DJ, Weintraub JA. The oral health burden in the United States: a summary of recent epidemiologic studies. J Dent Educ. 1993;57:853-62.
6. Beltrán-Aguilar ED, Barker LK, Canto MT, et al. Centers for Disease Control and Prevention (CDC) surveillance for dental caries, dental sealants, tooth retention, edentulism, and enamel fluorosis – United States, 1988-1994 and 1999-2002. MMWR Surveill Summ. 2005;54:1-43.
7. US Public Health Service, Division of Public Health Methods. US national health survey. Loss of teeth, United States, July 1957-June 1958. Washington: US Department of Health, Education, and Welfare, Public Health Service; 1960. DHEW publication 584–B22.
8. Holm-Pedersen P, Schultz-Larsen K, Christiansen N, Avlund K. Tooth loss and subsequent disability and mortality in old age. J Am Geriatr Soc. 2008;56:429-535.

9. Heitmann BL, Gamborg M. Remaining teeth, cardiovascular morbidity and death among adult Danes. Prev Med. 2008; 47(2):156-60.
10. Demmer RT, Jacobs DR Jr., Desvarieux M. Periodontal disease and incident type 2 diabetes mellitus: results from the First National Health and Nutrition Examination Survey and its epidemiologic follow-up study. Diabetes Care. 2008; 31(7):1373-9.
11. Okoro CA, Balluz LS, Eke PI, Ajani UA, Strine TW, Town M, Mensah GA, Mokdad AH. Tooth loss and heart disease: findings from the Behavioral Risk Factor Surveillance System. Am J Prev Med. 2005;29:50-6.
12. Hung HC, Joshipura KJ, Colditz G, Manson JE, Rimm EB, Speizer FE, Willett WC. The association between tooth loss and coronary heart disease in men and women. J Public Health Dent. 2004; 64:209-15.
13. Joshipura KJ, Hung HC, Rimm EB, Willett WC, Ascherio A. Periodontal disease, tooth loss, and incidence of ischemic stroke. Stroke. 2003;34:47-52.
14. Abnet CC, Qiao YL, Mark SD, Dong ZW, Taylor PR, Dawsey SM. Prospective study of tooth loss and incident esophageal and gastric cancers in China. Cancer Causes Control. 2001;12:847-54.
15. Frisk F, Hakeberg M, Ahlqwist M, Bengtsson C. Endodontic variables and coronary heart disease. Acta Odontol Scand. 2003;61:257-62.
16. Taguchi A, Sanada M, Suei Y, Ohtsuka M, Lee K, Tanimoto K, Tsuda M, Ohama K, Yoshizumi M, Higashi Y. Tooth loss is associated with an increased risk of hypertension in post-menopausal women. Hypertension. 2004;43:1297-300.
17. Behle JH, Papapanou PN. Periodontal infections and atherosclerotic vascular disease: an update. Int Dent J. 2006; 56:256-62.
18. Cabrera C, Hakeberg M, Ahlqwist M, et al. Can the relation between tooth loss and chronic disease be explained by socio-economic status? A 24-year follow-up from the population study of women in Gothenburg, Sweden. Eur J Epidemiol. 2005;20:229-36.
19. Tu YK, Galobardes B, Smith GD, McCarron P, Jeffreys M, Gilthorpe MS. Associations between tooth loss and mortality patterns in the Glasgow Alumni Cohort. Heart. 2007;93:1098-103.
20. Massey JT, Moore TF, Parsons VL, Tadros W. Design and estimation for the National Health Interview Survey, 1985-94. National Center for Health Statistics. Vital Health Stat. 1989;2. [cited 2008 Oct 15]. Available from: http://www.cdc.gov/nchs/data/series/sr_02/sr02_110.pdf
21. Gilbert GH, Litaker MS. Validity of self-reported periodontal status in the Florida dental care study. J Periodontol. 2007; 78(7 Suppl):1429-38.
22. Gilbert GH, Chavers LS, Shelton BJ. Comparison of two methods of estimating 48-month tooth loss incidence. J Public Health Dent. 2002;62:163-9.
23. Gilbert GH, Duncan RP, Kulley AM. Validity of self-reported tooth counts during a telephone screening interview. J Public Health Dent. 1997;57:176-80.
24. Douglass CW, Berlin J, Tennstedt S. The validity of self-reported oral health status in the elderly. J Public Health Dent. 1991;51:220-2.
25. Calle EE, Terrell DD. Utility of the National Death Index for ascertainment of mortality among cancer prevention study II participants. Am J Epidemiol. 1993;137:235-41.
26. Edlavitch SA, Baxter J. Comparability of mortality follow-up before and after the National Death Index. Am J Epidemiol. 1988;127:1164-78.
27. Stampfer MJ, Willett WC, Speizer FE, Dysert DC, Lipnick R, Rosner B, Hennekens CH. Test of the National Death Index. Am J Epidemiol. 1984;119: 837-9.
28. National Center for Health Statistics, Office of Analysis and Epidemiology. The 1986-2000 National Health Interview Survey linked mortality files: matching methodology. Hyattsville, MD: National Center for Health Statistics, Office of Analysis and Epidemiology; 2005. [cited 2008 Oct 15]. Available from: http://www.cdc.gov/nchs/data/datalinkage/matching_methodology_nhis_final.pdf
29. Osterberg T, Carlsson GE, Sundh V, Steen B. Number of teeth – a predictor of mortality in the elderly? A population study in three Nordic localities. Acta Odontol Scand. 2007;65:335-40.
30. Morita I, Nakagaki H, Kato K, Murakami T, Tsuboi S, Hayashizaki J, Toyama A, Hashimoto M, Simozato T, Morishita N, Kawanaga T, Igo J, Sheiham A. Relationship between survival rates and numbers of natural teeth in an elderly Japanese population. Gerodontology. 2006;23:214-8.
31. Centers for Disease Control and Prevention (CDC). Total tooth loss among persons aged >65 years – selected states, 1995-1997. MMWR Morb Mortal Wkly Rep. 1999;48:206-10.
32. Nowjack-Raymer RE, Sheiham A. Numbers of natural teeth, diet, and nutritional status in US adults. J Dent Res. 2007;86:1171-5.
33. Burt BA, Ismail AI, Morrison EC, Beltran ED. Risk factors for tooth loss over a 28-year period. J Dent Res. 1990;69:1126-30.
34. Eklund SA, Burt BA. Risk factors for total tooth loss in the United States; longitudinal analysis of national data. J Public Health Dent. 1994;54:5-14.
35. Sheiham A. Oral health, general health and quality of life. Bull World Health Organ. 2005;83:641-720.
36. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol. 2005;33:81-92.