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Social stratification and tooth loss among middle-aged and older Americans from 1988 to 2004

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Abstract – *Objectives:* Tooth retention has improved over the past few decades, but it is not known whether these trends have been observed across all demographic/socioeconomic subgroups. We examined number of missing teeth among dentate individuals (n = 9, 113) as well as edentulism and systematically modeled their trends over time by using clinical examination data. *Methods:* We investigated the association between social stratification and trends in tooth retention among adults ages 50+ from 1988 to 2004, using four waves of the National Health and Nutrition Examination Surveys (NHANES) (n = 11 812). *Results:* The prevalence of edentulism declined from 24.6% in NHANES III (1988–1994) to 17.4% in 2003–2004, and the mean number of missing teeth declined from 8.19 to 6.50. Older participants, Blacks, the less educated and those with lower income were higher on both edentulism and number missing teeth. Both edentulism and number of missing teeth declined over time, but their patterns varied. For edentulism, age and socioeconomic related disparities decreased over time due to more decline among older and low-income participants. For missing teeth, there was less decrement among older and low-income participants, resulting in increased age and socioeconomic related disparities. *Conclusions:* Our study found disparities in trends of tooth loss across demographic/socioeconomic strata. Findings suggest that racial/ethnic disparities are partially explained by socioeconomic status. Interventions designed to improve oral health for older adults, particularly those with low levels of income, need special attention.

Key words: edentulism; middle-aged; older adults; tooth loss; trends

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Previous studies show tooth retention has improved in the United States (US) since the 1970s (1–3). A report conducted by the National Center for Health Statistics using the National Health and Nutrition Examination Surveys of 1988–1994 (NHANES III) and NHANES 1999–2004 found that among adults aged 65–74 years the prevalence of edentulism declined over these two-time periods from 29% to 24%. The number of missing teeth decreased from 8.67 to 8.32 for the same age group (1). This report only addressed the overall prevalence of missing teeth and edentulism. Research has documented strong and persistent patterns of social disparities with respect to many health outcomes (4). However, the impact of social stratification on trends of oral health outcomes, such as tooth retention, over the past two decades has not been systematically analyzed.

Among the few published papers, one revealed that between 1971 and 2001, for those in a low socioeconomic position, the prevalence of edentulism declined from 50% to 32% in adults age 55–64 and 58%–43% among those age 65–74; the comparable declines for these age groups for individuals in a high social economic position were 22%–6%

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and 30%–9%, respectively (2). Another study based on self-reported data from a national survey showed that disparities in trends of edentulism persisted across racial/ethnic groups (3). Relative to Whites, Blacks, and Native Americans had a higher rate of edentulism, whereas the rate of edentulism was lower among Hispanics and Asians. While these studies have provided useful information to the field, edentulism is only one oral health outcome that measures tooth retention. It is important to examine tooth retention measured by both edentulism and the number of missing teeth together in the same population to estimate the effect of social stratification on these trends. Furthermore, although previous studies have examined oral health disparities across racial/ethnic groups and socioeconomic status, with the availability of more sophisticated statistical software packages, more advanced analytical methods need to be incorporated to examine the disparities and social stratification in a dynamic way.

This study aimed to investigate disparities in tooth loss, measured as rate of edentulism and the number of missing teeth, across sociodemographic and economic subgroups in adult populations aged 50+ between 1988 and 2004 using clinical examination data from a national representative sample.

Methods

Sample

Data were obtained from the NHANES conducted from 1988 to 1994 and from 1999 to 2000, 2001 to 2002, and 2003 to 2004. The NHANES are regularly administered nationally representative health surveys of the noninstitutionalized population of the US. The survey design has been well documented (5). Briefly, it utilizes a multistage household probability sample from which selected individuals are interviewed and examined. 8654, 2420, 2563, and 2510 persons with age 50 or over were interviewed in NHANES III, NHANES 1999–2000, NHANES 2001–2002, and NHANES 2003–2004, respectively. Of those, 7155, 2156, 2293, and 2327 in these four surveys had an oral health examination. At the same time, there were 1007 (NHANES III), 471 (NHANES 1999–2000), 341 (NHANES 2001–2002), and 300 (NHANES 2003–2004) cases with missing data. Excluding these cases left 6148, 1685, 1952, and 2027 in the analytical samples for the four NHANES surveys. The resulting overall sample size for the analysis was 11 812.

Study variables

Edentulism and the number of missing teeth were determined by a trained licensed dentist during an oral health examination. Third molars were excluded from the counts presented here as they are typically removed by choice, resulting in a possible range of 0–28 missing teeth. Demographic information including age, race, sex, and years of education was provided in the accompanying questionnaire. Persons older than age 85 were coded as age 85. In this study, the racial/ethnic variable was coded as White (non-Hispanic), Black (non-Hispanic), Mexican American (as specified in the NHANES data) or Other. In the rest of the manuscript, we refer these three racial/ethnic groups as White, Black, and Mexican American. Other race/ethnicity included Asians, Native Americans and Hispanics whose country of origin was not Mexico. These groups classified within 'Other' were not sampled in sufficient numbers to allow precise population estimates. Education was coded as <9 years of education, 9–11 years, 12 years, some college and college or more. Poverty was assessed based on the Poverty Index or the ratio of total family income to the US poverty level computed by the US Census Bureau (5). For consistency in examining trends over time, we grouped participants into quartiles, with Q1 representing those with the lowest values on the Poverty Index and therefore the lowest income and those in Q4 with the highest income. Quartiles were determined for each NHANES wave separately based on poverty levels among those adults of age 50 or older who participated in the oral health examination. Education and poverty/income were treated as categorical in the descriptive analyses to provide more information. These categories, however, had a linear relationship with the outcomes and were treated as continuous variables in the regression analysis for ease of interpretation. Time was coded as 0 for NHANES III (1988–1994), 8.5 for NHANES 1999–2000, 10.5 for NHANES 2001–2002 and 12.5 for NHANES 2003–2004, a way to reflect the midpoint of the data collection period for each round.

Statistical analyses

We first estimated the odds of edentulism across the multiyear period using logistic regression models. Among dentate participants (those with one or more permanent teeth) we estimated counts of missing teeth using negative binomial models because overdispersion was present (6). SAS software (Version 9.3) (7) was used for the descriptive

analyses. Because our analyses addressed whether changes over time varied with ethnicity (a group by time interaction), we used STATA (Version 12) software (8) to estimate both the logistic and negative binomial models. As discussed in Rothman, Greenland, and Lash (2008) (9), and Mustillo et al., (2012) (10) interactions in logistic and negative binomial models should be addressed on an additive scale (effects on disease prevalence) rather than on a multiplicative scale (effects on an odds or rate ratio). This can be performed using STATA's 'margins' postestimation command.

We used clinical examination sampling weights to reflect the characteristics of the US population at each of the four waves of the NHANES assessments. All statistical tests were two-sided and adjusted to take stratification and clustering (design) effects into account. Because of the large sample, statistical significance was defined as $P < 0.01$ to minimize the capitalization of chances.

For each set of models, we began with a model controlling for time, age, race, and sex (Model 1), followed by education and poverty quartile (Model 2). Product terms between each of the predictor variables and time were tested and left in the model if they were significant.

Results

The characteristics of the sample of participants of age 50 or older for each of the four waves are shown in Table 1. The education level of the population increased over the analysis period from 1988–1994 to 2003–2004 ($P < 0.0001$).

Overall, the prevalence of edentulism declined over the study period, from a prevalence of 24.6% in 1988–1994 to 17.4% in 2003–2004. To test the significance of a slight increase in edentulism in 2003–2004 following a period of decline, we evaluated a spline term in the model to reflect the change in the fourth wave. A spline term is a polynomial term added to the regression model which allows for a nonlinear change in slope. The term was not significant either in a model controlling only for time or in the model controlling for age, race, and sex for both outcomes, and hence the spline term was removed.

A total of 9113 of the 11 812 participants were dentate and were used to estimate the models for the counts of missing teeth. The characteristics of this sample are shown in Table 2. The dentate sample appeared to be younger and have more years of education and higher income compared with the study sample that included those who were edentulous. The mean number of missing teeth in this sample appeared to decline over the study period from 8.19 in 1988–1994 to 6.50 in 2003–2004. A similar increase in the number of missing teeth in 2003–2004 tested through the use of spline term was also not significant.

In the unadjusted model, the probability of edentulism decreased over time (odds ratio = 0.96, $P < 0.0001$) (results not shown). The adjusted odds

Table 1. Characteristics of the total study sample (n = 11 812)

Characteristic	1988–1994 (n = 6148) (%)	1999–2000 (n = 1685) (%)	2001–2002 (n = 1952) (%)	2003–2004 (n = 2027) (%)	Total (n = 11 812) (%)
No. 65 or older	3463(47.3)	904(42.1)	1064(41.9)	1188(43.2)	6619(43.6)
No. Female	3148(54.6)	843(53.3)	951(53.1)	1025(53.1)	5967(53.5)
No. White	3459(83.1)	877(78.3)	1218(81.3)	1224(80.6)	6778(80.8)
No. Black	1308(8.4)	281(7.7)	327(8.4)	324(9.1)	2240(8.5)
No. Mexican American	1162(2.6)	391(3.3)	299(3.2)	382(3.8)	2234(3.3)
No. Other Race/Ethnicity	219(5.8)	136(10.7)	108(7.1)	97(6.4)	560(7.4)
No. <9 Years Education	2104(19.7)	438(11.9)	351(9.6)	439(10.4)	3332(12.6)
No. with 9–11 Years Education	1030(15.6)	317(17.6)	294(12.9)	276(11.0)	1917(14.0)
No. with 12 Years Education	1637(33.0)	381(28.1)	440(24.8)	478(26.4)	2936(27.8)
No. with Some College	678(14.5)	312(23.4)	451(25.4)	492(29.2)	1933(23.6)
No. with College or More	699(17.1)	237(19.0)	416(27.3)	342(23.0)	1694(21.9)
No. in Q 1	1509(13.9)	377(15.5)	464(17.8)	508(15.1)	2858(15.6)
No. in Q 2	1489(19.1)	434(20.9)	467(19.2)	503(20.7)	2893(20.0)
No. in Q 3	1559(28.6)	421(27.1)	515(28.2)	471(26.2)	2966(27.4)
No. in Q4	1591(38.4)	453(36.5)	506(34.8)	545(38.1)	3095(37.0)
No. Edentulous	1580(24.6)	326(18.6)	362(16.0)	425(17.4)	2693(18.9)

Numbers are from unweighted data; Percentages are weighted to reflect population.
No. in Q1: number of individuals on the Poverty Index and with the lowest income quartile. Those in Q4 were in the highest income.

Table 2. Characteristics of the dentate study sample (n = 9113)

Characteristic	1988–1994 n = 4568 (%)	1999–2000 n = 1358 (%)	2001–2002 n = 1588 (%)	2003–2004 n = 1599 (%)	Total n = 9113 (%)
No. 65 or older	2307(42.2)	656(36.4)	796(37.9)	858 (38.1)	4617(38.5)
No. Female	2314(54.4)	663(51.6)	765(52.4)	807(52.6)	4549(52.7)
No. White	2453(82.5)	695 (78.2)	988(81.8)	951(80.5)	5087(80.7)
No. Black	949(8.2)	212(7.3)	258(8.2)	250(8.8)	1669(8.2)
No. Mexican American	1000(3.1)	347(3.8)	260(3.3)	320(4.2)	1927(3.6)
No. Other Race/Ethnicity	166(6.3)	104(10.7)	82(6.7)	78(6.6)	430(7.5)
No. <9 Years Education	1376(14.7)	327(9.3)	241(7.2)	290(7.7)	2234(9.4)
No. with 9–11 Years Education	714(13.8)	231(15.4)	206(10.5)	181(8.4)	1332(11.7)
No. with 12 Years Education	1282(33.9)	295(26.8)	350(23.6)	379(26.0)	2306(27.1)
No. with Some College	563(16.3)	275(25.7)	390(27.0)	422(31.0)	1650(25.7)
No. with College or More	633(21.3)	230(22.8)	401(31.8)	327(27.0)	1591(26.1)
No. in Q 1	1014(10.7)	275(12.7)	309(14.2)	341(11.7)	1939(12.4)
No. in Q 2	997(16.3)	320(17.5)	359(17.6)	372(19.0)	2048(17.7)
No. in Q 3	1160(27.9)	341(27.3)	443(28.8)	386(26.2)	2330(27.5)
No. in Q4	1397(45.1)	422(42.5)	477(39.4)	500(43.1)	2796(42.4)
Mean No. of Missing Teeth (SD)	8.19(0.18)	7.37(0.28)	6.08(0.34)	6.50(0.33)	6.94(0.15)

Numbers are from unweighted data; Means and percentages are weighted to reflect population.
No. in Q1: number of individuals on the Poverty Index and with the lowest income quartile. Those in Q4 were in the highest income.

ratio was essentially unchanged when age, race, and sex were added to the model (Table 3, Model 1). Table 3 shows the associations between sociodemographic/economic variables and the odds of edentulism. Averaged over time, older (age 65 or older) participants had higher odds of edentulism compared with those ages 50–64. Compared with Whites, Blacks had a higher and Mexican Americans a lower probability of edentulism over time. Having fewer years of education and lower income were associated with higher odds of edentulism. As shown in Model 2, the racial/ethnic disparities noted changed when education and income were added to the model. Specifically, being Black was associated with lower odds of edentulism when education and income were controlled. Similarly, the lower odds of edentulism observed among Mexican Americans more than doubled when education and income were controlled.

Figures 1 and 2 present the results of the margins postestimation models and show the effect of time on the probability of edentulism differed by age and level of income. The probability of edentulism among individuals of age 65 or older declined more compared with those of age 50–64. Specifically, those ages 50–65 had a slope of −0.004 while those of age 65 and older had a slope of −0.008. Both individual slopes were significant ($P < 0.0001$), and the difference between the slopes was significant on an additive scale ($Z = 3.88$, $P < 0.001$). The probability of edentulism among those in the lowest income quartile also more declined compared with those in quartiles 2–4 ($Z = 2.96$, $P < 0.01$). All of the individual slopes were significant ($P < 0.0001$). Slopes were as follows: Q1:

Table 3. Associations between sociodemographic/economic variables averaged over time on the odds of edentulism (n = 11 812)

	Model 1			Model 2		
Variable	OR	99% CI	P	OR	99% CI	P
Intercept	0.16	0.13,0.21	<0.0001	1.13	0.85,1.49	0.2620
Time	0.96	0.94,0.99	<0.0001	0.98	0.96,1.00	0.0030
Age 65 or older	2.99	2.57,3.48	<0.0001	2.08	1.79,2.40	<0.0001
Female	1.11	0.96,1.30	0.0660	0.96	0.81.1.15	0.5660
Race/Ethnicity						
Black	1.27	1.00,1.61	0.0090	0.70	0.54,0.90	<0.0001
Mexican American	0.56	0.35,0.89	0.0020	0.19	0.12,0.30	<0.0001
Other	1.15	0.76,1.75	0.3700	0.61	0.44,0.86	<0.0001
Yrs of Education				0.61	0.56,0.65	<0.0001
Poverty Ratio				0.67	0.61,0.74	<0.0001

OR = Odds ratio.

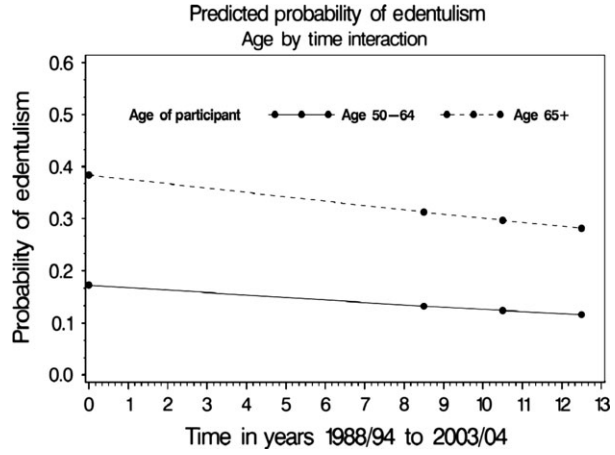

Fig. 1. Predicted Probability of Edentulism by Age Over Time.

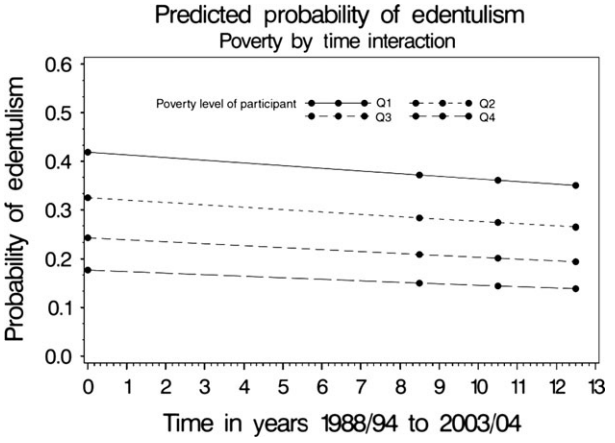

Fig. 2. Predicted Probability of Edentulism by Poverty Level Over Time.

−0.004, Q2: −0.003, Q3: −0.002, and Q4: −0.001. The change for each of the other three quartiles was significantly different from the change noted for Quartile 1. Despite these differential changes, the relative positions of the subgroups considered did not change.

The number of missing teeth decreased over time (incidence rate ratio = 0.98; $P < 0.0001$). This observed decrease was not significantly affected when age, race, and sex were added to the model. As shown in Table 4, among dentate participants, being older (age 65 or more) or Black compared with White was associated with more missing teeth over time. Having fewer years of education and lower income were also associated with more missing teeth. When education level and income were included in addition to age, race, and sex, Mexican Americans had a fewer number of missing teeth than their White counterparts. The incidence rate ratio (IRR) changed from 1.65 (1.47, 1.84) to 1.37 (1.22, 1.55) when education and income were added to the model. Disparities between Blacks and Whites were reduced by 43% [(0.65 − 0.37)/0.65], and this reduction was statistically significant ($P < 0.01$). In addition, females were more likely to have fewer missing teeth compared with males.

Figures 3 and 4 show from the margins postestimation models that age disparities in the number of missing teeth increased over time while racial/ethnic disparities decreased. Specifically, those ages 50–64 and nonwhites (particularly Blacks and those of other race) had a sharper decrease in the number of missing teeth compared with older adults and Whites. The slope for those ages 50–64 was −0.17 ($P < 0.0001$) while the slope for those of age 65 or older was −0.08 ($P = 0.02$). The difference in slopes was significant ($Z = -2.63$, $P < 0.01$). The slope for Whites was −0.14, Blacks was −0.24, Mexican Americans was −0.16 and Other race was −0.21. The slopes for each of the four groups were significant ($P < 0.0001$). The slope for Whites was significantly different from nonwhites ($Z = -3.74$, $P < 0.0001$). Whites differed from Blacks ($Z = 4.33$, $P < 0.0001$)

Table 4. Associations between sociodemographic/economic variables averaged over time on the number of missing teeth ($n = 9113$)

	Model 1			Model 2		
Variable	IRR	99% CI	*P*	IRR	99% CI	*P*
Intercept	6.28	5.55,7.10	<0.0001	16.55	14.01,19.55	<0.0001
Time	0.98	0.97,0.99	<0.0001	0.98	0.97,0.99	<0.0001
Age 65 or older	1.64	1.48,1.83	<0.0001	1.46	1.32,1.62	<0.0001
Female	0.97	0.89,1.06	0.3700	0.91	0.84,0.97	0.0010
Race/Ethnicity						
Black	1.65	1.47,1.84	<0.0001	1.37	1.22,1.55	<0.0001
Mexican American	1.10	0.91,1.32	0.1840	0.71	0.58,0.85	<0.0001
Other	1.40	1.19,1.65	<0.0001	1.17	1.00,1.37	0.0090
Yrs of Education				0.79	0.76,0.83	<0.0001
Poverty Ratio				0.83	0.79,0.87	<0.0001

IRR = Incidence rate ratio.

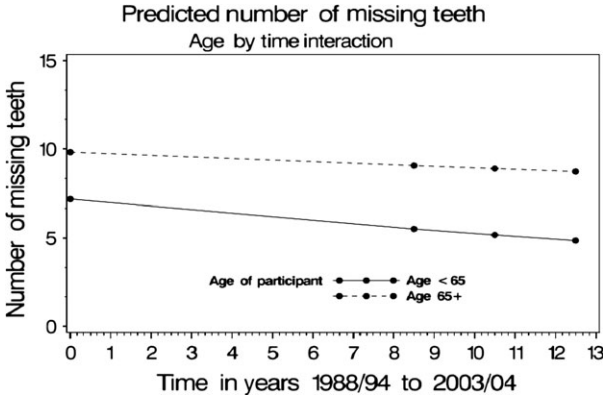

Fig. 3. Predicted Number of Missing Teeth by Age Over Time.

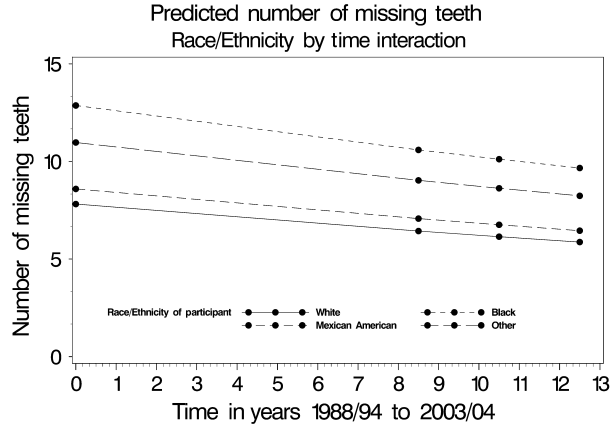

Fig. 4. Predicted Number of Missing Teeth by Race/Ethnicity Over Time.

and Other race ($Z = 3.50$, $P < 0.0001$) but not from Mexican Americans ($Z = 1.65$, $P = 0.10$).

The effect of time did not differ by level of education, but income disparities increased over time. Those in quartiles 3 and 4 showed a significant decline in missing teeth while those in quartiles 1 and 2 did not. The slopes for the different quartiles were Q1 (highest level of poverty): 0.08 ($P = 0.25$), Q2: −0.03 ($P = 0.30$). Q3: −0.12 ($P < 0.0001$) and Q4: −0.14 ($P < 0.0001$). As shown in Fig. 5, those in the higher three income quartiles saw a sharper decrease in the number of missing teeth compared with those in the lowest quartile ($Z = -2.98$, $P < 0.01$). Despite these differential changes noted for age, race, and poverty, the relative positions of the subgroups did not change over time.

Discussion

This study extends previous research on tooth loss by (i) focusing on the number of missing teeth among dentate individuals as well as on edentulism; (ii) systematically modeling trends over time (the analysis technique that was not available previously); and (iii) using clinical examination data rather than self-reported dental status. Using the NHANES data for Americans aged 50 and above from 1988–1994 to 1999–2004, we found that variations in terms of age and socioeconomic status at each time point were similar across outcomes. Older (age 65+) participants, Blacks, the less educated, and those with lower incomes had higher rates of edentulism and more missing teeth. When education and income were controlled, racial/ethnic differences in edentulism was significantly reduced in that being Black was associated with lower odds of edentulism. While we found an overall decrease in both edentulism and the number of missing teeth for American adults ages 50 and above between 1988 and 2004, subgroup specific patterns of change differed across outcomes. For edentulism, age and income-related disparities decreased between 1988 and 2004, with more decline in the older and low-income groups compared with others. For number of missing teeth, age, and income-related disparities increased with a sharper decline among younger persons and the more affluent. Additionally, while change in edentulism was unrelated to ethnicity, racial disparities decreased on missing teeth. These divergent patterns of change over time have clear public health implications with regard to which at-risk groups might be targeted for intervention.

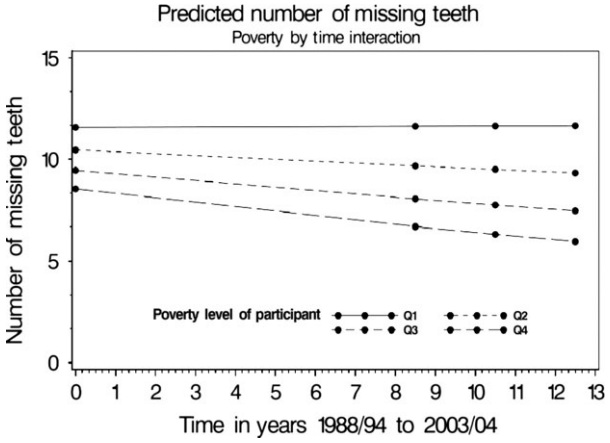

Fig. 5. Predicted Number of Missing Teeth by Poverty Level Over Time.

Using the NHANES data, we found an overall decrease in tooth loss (i.e., in the rate of edentulism and the number of missing teeth) for American adults aged 50 and above in the period from 1988–1994 to 2004. The number of teeth lost and

frequency of edentulism substantially differed across age, race/ethnicity, years of education, and levels of income. For instance, those older and Black (in comparison with White) and having fewer years of education and lower income had a higher risk of being edentulous. For dentate individuals, these factors were also associated with having more missing teeth. In addition, over time, those in the older age group and in the lowest income quartile had a greater decline in the probability of being edentulous compared with those in younger age groups and with higher levels of income. With regard to the number of missing teeth, age, and income disparities increased over time while racial disparities decreased.

Previous studies using NHANES data (2) and the National Health Interview Survey self-report data (3) have found that there has been a decrease in the rate of edentulism over the past several decades. Our study further illustrated that there was an improvement in tooth retention controlling for population heterogeneity (i.e., demographic characteristics and socioeconomic status). Previous studies have attributed the improvement in tooth retention to the decrease in smoking, the improvement of oral health literary, the increasing years of education, and more regular use of preventive dental care among more recent cohorts (2). Many other factors for which data were not available in this study could also contribute to the decrease of the edentulous rate, such as the introduction of fluoridation through community water treatment (11) and fluoridated toothpaste and mouth rinses (12). Health practices such as dietary supplements, and professionally applied or prescribed gel, foam, and varnish may also contribute to improved tooth retention (11, 12). Others point to advancements in dental technologies and treatment modalities, changes in patient and provider attitudes and treatment preferences, improved oral hygiene, and regular use of dental services (13).

While there was an overall improvement in tooth retention, our study found disparities in trends of tooth loss across socioeconomic strata. Using NHANES data, one previous study showed that the difference in the rate of edentulism remained unchanged between low and high socioeconomic status over the period from 1972 to 2001. Our study extends beyond previous research by examining both edentulism and the number of missing teeth. Rather than presenting unadjusted estimates of changes in the edentulous rate, we presented findings on trends in tooth retention in relationship to social stratification. We found complex trends of tooth loss among individuals with different ages and socioeconomic status. Those aged 65+ and those in the lowest income quartile declined more than others on edentulism; however, they declined less than others on missing teeth. Given that adults are retaining more of their natural teeth, interventions designed to assist individuals maintain healthy teeth become more critical.

Older adults are more likely to be receiving maintenance rather than preventive care, individuals with low income in particular. It is likely that individuals with low income are not able to afford dental treatment due to fewer resources and inaccessibility of dental insurance. For the past twenty years, although more advanced dental technologies and treatment modalities have been developed, many individuals with low income may have not received much benefit due to lack of financial resources. Public-assisted programs such as Medicaid have not expanded dental coverage in recent years, and these programs only cover limited dental services for low-income populations. Findings from our study suggest that reducing social disparities (e.g., education) in conjunction with improved access to dental care would contribute to better oral health overall and reduce oral health disparities.

Racial/ethnic disparities in oral health have been persistent over the past two decades. Our study provides a more complex picture of disparities in tooth loss than previous studies. Our results show that averaged over time, compared with Whites, Blacks had a higher and Mexican Americans had a lower probability of edentulism. However, after controlling for education and income, Blacks were less likely to be edentulous, and the probability became much lower for Mexican Americans. Using clinical examination data, our study results are consistent with a previous study that examined trends of self-reported edentulism using the National Health Interview Survey (1999–2008) (3). Our study shows that the results on the number of teeth missing differ from the outcome on edentulism with regard to racial/ethnic disparities. Our findings also provide new knowledge that while being Black compared with White was associated with more missing teeth over time, this disparity was reduced by 43% controlling for education and income; in the meantime, Mexican Americans had a lower number of missing teeth. These findings suggest that much of the racial/ethnic disparities are explained by socioeconomic status. Some

anecdotal evidence has suggested that minorities, such as Blacks, are particularly concerned about saving their teeth for esthetic reasons (14). We surmise the level of concern may be greater for those with relatively higher socioeconomic status. Further, racial disparities decreased over time. Specially, compared with Whites, the number of missing teeth decreased more for Blacks. This may reflect a beneficial effect of some recently developed programs and services in Black communities in addressing oral health disparities (15). Further studies are warranted regarding other oral health indicators such as dental caries and periodontal diseases across racial/ethnic groups in the U.S.

There are some limitations in this study. It would be ideal for us to include more recent waves of the data to examine the trends of oral health in the US. While NHANES has more recent waves of data after 2004, the oral health examination protocol in the recent waves is very different from the previous waves; thus, we are not able to use the later waves of the data for trend analysis. Because the focus of this study was social stratification, we did not include variables such as dental insurance, which may affect the types of dental treatment and consequently have an impact on trends of tooth loss. However, we need to be aware that insurance is a mediating variable which is highly correlated with education and income. In addition, other variables such as health beliefs and knowledge may affect these trends. Some of the effect sizes presented is quite small. However, this can be also seen as a strength as we were able to compile a sufficient number of participants enabling us to detect meaningful differences. The strengths of the study outweigh the limitations and include the use of a representative sample of the US population across a multiyear period and the utilization of results based on clinical dental examination data. Future studies are needed to continue trend analysis on other related oral health outcome measures such as periodontal disease and tooth decay.

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