The Association Between Community Water Fluoridation and Adult Tooth Loss

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Objectives. We sought to estimate the association between community water fluoridation (CWF) exposure at various stages of life and adult tooth loss.

Methods. We used data from the 1995 through 1999 Behavioral Risk Factor Surveillance System, merged with data from the 1992 Water Fluoridation Census, to estimate interval regression models that relate CWF exposure with tooth loss.

Results. Our results indicate that CWF levels in the county of residence at the time of the respondent's birth are significantly related to tooth loss but current CWF levels are not. In addition, the impact of CWF exposure is larger for individuals of lower socioeconomic status.

Conclusions. This study suggests that the benefits of CWF may be larger than previously believed and that CWF has a lasting improvement in racial/ethnic and economic disparities in oral health. (*Am J Public Health.* 2010;100:1980–1985. doi:10.2105/AJPH.2009.189555)

Community water fluoridation (CWF) is one of the most commonly provided local public goods in the United States. Studies have demonstrated a clear inverse relationship between dental caries and contemporaneous exposure to CWF, particularly among children,[1–5] but little is known about the long-term impact of CWF exposure on adult oral health. We focused on estimating the association between CWF exposure at various stages of life and adult tooth loss.

Fluoride plays a crucial role in maintaining good oral health by combating the demineralization of enamel initiated by the caries process.[6] The addition of controlled amounts of fluoride to the public water supply could affect tooth loss in adulthood in 3 ways. First, by reducing the incidence of childhood dental caries, fluoride could reduce the likelihood of unchecked caries in which bacteria penetrate the underlying dentin and then progress into the pulp, resulting in pulpal necrosis and subsequent tooth extraction.[7] Second, exposure to fluoride prior to tooth eruption may alter the composition of enamel, a highly mineralized tissue composed almost entirely of hydroxyapatite crystals.[8] If fluoride is incorporated into these crystals, they become more permanently resistant to acid dissolution.[6] Third, exposure to CWF in adulthood may further improve oral health by providing continued protection of tooth enamel throughout life.[7] Despite the plausibility of these 3 mechanisms, dental caries can be effectively treated through dental interventions. Thus, inadequate treatment of dental caries must occur for CWF to have an impact on tooth loss.

A fuller understanding of factors that may relate to tooth loss is important because healthy teeth are a vital and visible component of general well-being. Teeth help in maintaining general health via nutrition,[9,10] make a substantial contribution to one's physical appearance,[11] and have significant impacts on one's earnings[12] and employment opportunities.[13–15] Therefore, tooth loss may substantially affect an individual's quality of life.

The goal of our study was to estimate the association between CWF exposure at various stages of life and adult tooth loss. We estimated this association by relating community-level measures of CWF at various time intervals, computed from data collected by the Centers for Disease Control and Prevention (CDC), to data on the oral health status of individuals who live in the same communities, obtained from the Behavioral Risk Factor Surveillance System (BRFSS), with controls for other characteristics of these communities. Community water fluoridation is, by design, a community-level intervention; thus, it is appropriate to assign a community-level measure of exposure to individuals. All individuals within a community are exposed to the identical CWF intervention, although individuals may vary in the amount of fluoride they ingest (because of differences in toothpaste choice or beverage consumption, for example).

METHODS

The 1992 Water Fluoridation Census compiled by the CDC contains detailed information on the fluoridation status of every public water system in the United States. Each state provided information to the CDC for all water systems within that state, including the date fluoridation began, whether the fluoride was naturally occurring or chemically adjusted, the county served by the water system, and the population served by the water system by county as of 1990.

To assign water fluoridation status to individuals, we computed county-level CWF based on the CWF of individual water districts within each county and the number of people served. Because there are often multiple fluoridating water districts within a county, we first aggregated the total number of people within a county with access to fluoridated water. Second, we computed county fluoridation rates in 1990 by dividing the total number of people within a county with access to fluoridated water by the total county population as listed from the 1990 US Census.[16] To determine county fluoridation rates for prior years, absent any alternative data source, we must assume that the percentage of the population served by each water system is constant over time. Using the date a county's fluoridation began, we assigned this same county fluoridation rate to the county for all years after fluoridation began and a rate of zero to all years prior to fluoridation, leaving us with a county–year panel of fluoridation rates.

To clarify this assignment process, consider a county with only 1 water district that fluoridates and began doing so in 1960. As of 1990, this water district served 1000 people, out of 5000 people living in the county, thus implying a fluoridation rate of 0.2. Because fluoridation began in 1960, we assigned a value of 0.2 to the years 1960 through 1990 and a value of 0.0 to all prior years.

Surveys

The BRFSS is an annual survey established by the CDC of more than 350 000 adults. This nationally representative survey elicits prevalence of major behavioral risks and health conditions among adults, consisting of "core questions" administered to all respondents and "module questions" administered in specific states. In addition to health information, the BRFSS collects numerous demographic variables, including each respondent's gender, race/ethnicity, age, education, marital status, employment status, insurance status, number of children, and income.

Beginning in 1995, an oral health module was administered in 24 states. In addition to questions regarding dental visits, the module asked the following question regarding tooth loss: "How many of your permanent teeth have been removed because of tooth decay or gum disease? Do not include teeth lost for other reasons, such as injury or orthodontics." Respondents were given 4 categories to choose from: (1) none; (2) 5 teeth or fewer; (3) 6 teeth or more but not all; and (4) all teeth (we excluded those with invalid responses). This module was asked in varying states over the next 3 years and became part of the core in 1999, thus covering all states.

Our analysis focused on survey data from 1995 to 1999 for individuals born during the years 1950 to 1969. We included only individuals born after 1950 to exclude those with no possibility of exposure to CWF. We excluded individuals born after 1969 to ensure sufficient time for tooth loss to occur.

We assigned 3 measures of fluoridation status: current, 20 years ago, and at birth. To do this, we merged the county–year fluoridation panel derived from the fluoridation census with the BRFSS according to the BRFSS respondent's current county of residence. We assigned current [county] CWF by using data from the last year of the county–year fluoridation panel (fluoridation rates have changed minimally since 1990). We assigned [current county] CWF 20 years ago by using data from 20 years before the BRFSS survey year of the county–year fluoridation panel. We assigned [current county] year of respondent birth CWF by using data from the year of birth of the BRFSS respondent of the county–year fluoridation panel. For example, for an individual born in 1955 and surveyed in 1999, we assigned fluoridation rates from 1999, 1979, and 1955.

We conducted statistical analyses by using the ordinal responses to the tooth loss question, but we also assessed the robustness of our results by imputing exact tooth loss numbers with the National Survey of Oral Health (NSOH) in US Employed Adults and Seniors (1985–1986). This survey was the first national study to establish the prevalence of dental caries and periodontal disease among adults. Publicly available data were collected from 15 132 employed adults (aged 18–64 years) given oral health examinations in their employment settings. The NSOH contains the exact number of teeth lost by each respondent, along with the individual's age and gender, which we used for imputation.

City and County Data Books

We also merged several county-level variables potentially confounded with CWF by using the City and County Data Books (CCDBs). The CCDBs, maintained by the US Census Bureau, are the most comprehensive source of information about all US counties with a population of more than 25 000. The CCDBs are derived from various public and private sources, such as the decennial census of population and housing. We included variables to account for area demographics, such as family income, population, age distribution, racial distribution, and mortality rate. Because we assigned CWF levels to individuals in the BRFSS at multiple time periods, we also included area demographic variables from the 1960, 1980, and 2000 CCDBs.[17–19]

Statistical Analysis

Our analysis focused on estimating the association between adult tooth loss and current CWF, CWF 20 years ago, and CWF at time of birth. The categorical responses to the tooth loss question can be viewed as interval-coded data. That is, the responses provided a range of values for exact tooth loss for those who responded as having lost 5 or fewer teeth or 6 or more but not all teeth. On the other hand, those who reported having lost zero or all teeth had an exact value of tooth loss (we assigned a value of 28 to "all teeth lost" because this did not include wisdom teeth). Therefore, we estimated interval regression models via maximum likelihood,[20] which are ideally suited to this type of data. Because fluoridation status is coded as the percentage of a county fluoridated, we can interpret coefficients from the interval regression as the change in the number of teeth lost by going from 0% to 100% fluoridated.

We estimated regressions for all individuals and also estimated separate regressions by completed education and race/ethnicity. We also included in our models numerous independent variables to account for possible confounding. Because decisions about CWF may be driven by the characteristics of individuals within an area, we included county-level covariates from the CCDBs for the years that roughly corresponded to the CWF variables. Individuals may make choices about fluoridation status and oral health, so we also included the individual-level covariates available in the BRFSS (described previously). Because age is an important determinant of tooth loss, we controlled for it nonparametrically by including a separate indicator variable for each year of age. Individuals born in later years or surveyed in later years may have been exposed to higher CWF levels but also may have had access to better dental care because of technological innovations, so we controlled for birth cohort effects by including separate dummy variables for each year of birth and survey year effects by including separate dummy variable for each survey year. Lastly, to control for statewide policies that may be correlated with both fluoridation status and oral health, we included separate dummy variables for each state.

To assess the robustness of our model to the assumptions of normality and homoskedasticity of the error terms imposed by interval regression, we also performed linear regression with imputed tooth loss, which gives consistent estimates even if these assumptions are violated.[20] To impute tooth loss for those with 1 to 5 or 6 to 27 lost teeth, we performed cold-deck imputation, which is a nonparametric method of imputation that preserves the true distribution of tooth loss.[21] Cold-deck imputation is performed by grouping respondents from the data set with missing values for exact tooth loss (BRFSS) with respondents from a donor data set without missing values (NSOH), and then randomly selecting a tooth loss value from a donor within the same group to serve as the imputed value for each respondent. We grouped respondents on the basis of age in 5-year cells, gender, and tooth-loss category (1–5 or 6-27). For example, for each individual in the BRFSS who was a man aged 40–44 years with 1–5 lost teeth, we randomly selected an individual from NSOH who was also a man aged 50–54 years with 1–5 lost teeth, and then assigned the exact tooth loss from the NSOH respondent to the BRFSS respondent.

TABLE 1—Summary Statistics for Tooth Loss and Community Water Fluoridation (CWF): 1992, 1995–1999 Behavioral Risk Factor Surveillance System, Birth Cohorts 1950–1969

	Observations	% or Mean	Current CWF, %	CWF, % 20 Years Ago	CWF, % at Birth
	Overall tooth loss				
Tooth loss category					
0	54 325	58.60%	49.6	43.5	23.4
1-5	31 297	33.76%	51.3	44.3	21.8
6-27	5728	6.18%	52.7	44.7	18.2
28	1351	1.46%	53.8	46.1	16.2
	Imputed tooth loss by race and education				
Race/ethnicity					
White	72 701	1.810	49.3	42.9	21.7
Black	8636	2.999	70.5	60.9	31.8
Education					
< High school degree	5883	4.647	50.1	42.3	22.4
High school degree	53 729	2.231	49.6	43.0	22.2
College degree	33 089	0.984	51.9	45.6	22.8

RESULTS

Table 1 provides summary statistics for our sample. Nearly 60% of respondents had no tooth loss, and fewer than 2% of respondents had lost all teeth (overall tooth loss). Average levels of current CWF and CWF 20 years ago were generally higher for those respondents with more tooth loss, but levels of CWF at birth were generally lower. Tooth loss was much higher for Blacks and for the less-educated (imputed tooth loss by race/ethnicity and education). Although there was a strong gradient in tooth loss by education, CWF rates were quite comparable. There is ample variation over time and across counties in CWF rates (not shown).

Table 2 presents our main regression results. Models 1 to 3 focus on interval regression with the 4 tooth-loss categories, and all regressions controlled for individual-level covariates. In model 1, we controlled only for current CWF and 2000 CCDB variables. We found a statistically significant estimate of –0.162, which implies that going from 0%–100% fluoridation is associated with having 0.16 more teeth. Current CWF may reflect prior CWF, so in model 2 we added to this regression controls for CWF 20 years ago in the same county as well as 1980 CCDB variables. The coefficient on current CWF decreased considerably to 0.002, suggesting that the observed correlation between current CWF and tooth loss was spurious. The coefficient on CWF 20 years ago was not statistically significant, but was the same magnitude as was the coefficient on contemporaneous CWF from model 1. In model 3, we present results that also add CWF at birth and CCDB variables from 1960. Again, the coefficient on contemporaneous CWF was small and not distinguishable from zero. Now, the coefficient on CWF 20 years ago became considerably smaller. The coefficient on CWF at birth, however, was statistically significant and large: going from 0%–100% fluoridation was associated with having 0.26 more teeth.

In model 4, we present estimates from a linear regression with imputed tooth loss, with controls for all CWF and CCDB variables comparable to those in model 3. The estimates are quite comparable to the interval regressions results: contemporaneous and CWF 20 years ago were not statistically significant, whereas CWF at birth was statistically significant and associated with having 0.26 more teeth.

In Table 3, we reproduced the interval regression results akin to models 1 and 3 from Table 2 except estimated separately by race/ethnicity and completed education. For Whites and for college-educated individuals, we did not find a statistically significant relationship between CWF at any time and tooth loss. For Blacks, we found a similar pattern to the main results: a statistically significant estimate for contemporaneous CWF that went away once we controlled for historical CWF. Furthermore, we found a statistically significant estimate for CWF at birth, even though the estimate for CWF 20 years ago, although not significant, is comparable in magnitude to the estimate for CWF at birth. For high school dropouts, we also found comparable patterns to those among Blacks, though no estimates were statistically significant, which may be attributable to the significant decrease in sample size. For high school graduates, we found similar patterns to Table 2: contemporaneous CWF switched from significant to insignificant when we controlled for CWF at birth, and CWF at birth was significant. The estimates for Blacks, for high school dropouts, and for high school graduates implied that going from 0%–100% fluoridated in the county at the time of birth is associated with having 0.37, 0.61, and 0.39 more teeth, respectively.

DISCUSSION

We observed 3 main findings. First, although we found a contemporaneous

TABLE 2—Association Between Tooth Loss and Current and Historical Community Water Fluoridation (CWF): 1995–1999 Behavioral Risk Factor Surveillance System, Birth Cohorts 1950–1969

	Model 1, b (SE)	Model 2, b (SE)	Model 3, b (SE)	Model 4, b (SE)
Current CWF	−0.162** (0.061)	0.002 (0.122)	0.061 (0.123)	0.114 (0.135)
CWF 20 y ago		−0.156 (0.116)	−0.083 (0.123)	−0.123 (0.136)
Birth CWF			−0.255** (0.066)	−0.261** (0.072)
Dependent variable	categorical	categorical	categorical	imputed
Regression model	interval	interval	interval	linear

Notes. There are 92 701 observations in all regressions. All regressions include separate indicator variables for year of birth, survey year, state of residence, and age; individual-level controls for gender, race, education, marital status, employment status, number of not good mental health days in past month, diabetic status, number of children, household income, and insurance status; and 2000 county-level controls for population, population per square mile, percentage of population White, percentage of population aged older than 65 years, percentage of population aged younger than 5 years, median age, median household income, and death rate. Models 2, 3, and 4 include 1980 county-level controls for same variables as 2000 county-level controls, and models 3 and 4 include 1960 county-level controls. Results in models 1 through 3 are based on interval regression with tooth loss categories as the dependent variable and model 4 is based on linear regression with imputed tooth loss as the dependent variable.
*$P<.05$; **$P<.01$.

correlation between CWF and adult tooth loss, this relationship disappeared once CWF levels from earlier years were added. This suggests that the contemporaneous CWF may be serving as a proxy for lifetime exposure: areas with higher levels of current CWF were also likely to have had higher levels of CWF in the past. Not controlling for earlier CWF levels led to a spurious relationship between contemporaneous CWF and tooth loss.

Second, we found that CWF levels in the respondent's county of residence at the time of birth were significantly related to tooth loss. Our results imply that for every 4 individuals currently living in a county that fluoridated at their times of birth, 1 individual had 1 more tooth than if those individuals had not lived in a county that fluoridated. This finding is consistent with the hypothesis of a lasting effect from fluoridation exposure.[8] Although there is some debate regarding the optimal timing of fluoride exposure in relation to tooth eruption, these first 2 findings are consistent with previous evidence that the impacts of fluoride exposure are less important once permanent teeth have formed.[22]

Third, the impact of CWF exposure is larger for individuals of lower socioeconomic status (SES) than for individuals of higher SES. Lower-SES individuals may be less able than are higher-SES individuals to compensate for the occurrence of dental caries through dental interventions. For example, the rate of annual, preventive dental care visits is considerably higher among higher-SES individuals.[23] The evidence of small, statistically insignificant estimates for college graduates is also consistent with the notion that adequate treatment of dental caries nullifies the impact of CWF on tooth loss.

Limitations

A significant concern with our analysis is the assignment of fluoridation exposure. First, to assign fluoridation status, we would ideally like to assign individuals to their water district, but the BRFSS identifies only the county of residence. Therefore, we computed a countywide measure of fluoridation status based on the status of water districts within the county, and assigned individuals to this countywide average. (This assignment is distinct from the ecological fallacy: we observed individuals in our data; if we could identify the water district that served them, we would precisely assign their fluoridation exposure and there would be no ecological concern.) From a statistical perspective, this new measure introduced little concern—the coefficients from a variable on the unit interval can be interpreted as the change of going from no fluoridation to full fluoridation. However, the measure introduced measurement error because we were assigning the probability of fluoridation exposure when in fact, an individual was either exposed to flouridation or not.

The second concern is that we assigned historical fluoridation status to a respondent on the basis of the respondent's current county of residence. Respondents, however, may not have lived in the same county for their entire lives. Indeed, there is considerable mobility throughout the United States, so earlier assignments of CWF are likely to be measured with even more error than is contemporaneous CWF. Although there were little data available to improve upon these measurement issues, we could assess the potential direction of bias this introduced to our estimates. Evidence suggests that CWF status does not have a statistically significant relationship with mobility decisions.[12] Therefore, any measurement error in CWF assignment would be random, often referred to as "classical measurement error." Standard derivations show that classical measurement error biases estimates toward the null.[20] If this were true in our sample, then our estimates would reflect a lower bound of the true relationship, particularly for the historical estimates, and, hence, would understate the full impacts of CWF.

An additional concern in our analysis is potential confounding: unobserved factors correlated with fluoridation status may also be correlated with oral health. For example, wealthier areas may be more likely to fluoridate, but may also have better access to dental care. Although we have no way of directly testing for the presence of such unobserved factors, we note that our analysis controlled for numerous potentially confounding variables. With respect to the wealth example, we controlled for both median family income of the county and income of the respondent. Furthermore, as shown in Glied and Neidell,[12] CWF status during the 1950s and 1960s was uncorrelated with numerous observable county-level factors. If CWF status were uncorrelated with these observable factors, CWF status would more likely be uncorrelated with the unobservable factors as well.

Evidence indicates that the impacts of CWF are much smaller today than they were 50 years ago, so an additional concern with our analysis is external validity. Some of the

TABLE 3—Association Between Tooth Loss and Community Water Fluoridation (CWF) by Race and Education: 1995–1999 Behavioral Risk Factor Surveillance System, Birth Cohorts 1950–1969

	White, b (SE)	Black, b (SE)	<High-School Degree, b (SE)	High-School Degree, b (SE)	College Degree, b (SE)
Current CWF only					
Current CWF	−0.090 (0.063)	−0.622** (0.207)	−0.654 (0.364)	−0.215** (0.079)	−0.011 (0.048)
Current and historical CWF					
Current CWF	0.013 (0.114)	0.118 (0.349)	−0.113 (0.611)	0.079 (0.151)	0.048 (0.107)
CWF 20 y ago	−0.007 (0.119)	−0.556 (0.341)	−0.216 (0.584)	−0.052 (0.155)	−0.073 (0.113)
Birth CWF	−0.186* (0.075)	−0.372* (0.179)	−0.609 (0.404)	−0.389** (0.086)	−0.057 (0.060)
Observations	72 701	8636	5883	53 729	33 089

Notes. All regressions include separate indicator variables for year of birth, survey year, state of residence, and age; individual-level controls for gender, race, education, marital status, employment status, number of not good mental health days in past month, diabetic status, number of children, household income, and insurance status; and 2000 county-level controls for population, population per square mile, percentage of population White, percentage of population aged older than 65 years, percentage of population aged younger than 5 years, median age, median household income, and death rate. All estimates are based on interval regression with tooth loss category as the dependent variable.
*$P < .05$; **$P < .01$.

explanations for a smaller impact include greater availability of alternative fluoride sources, such as fluoridated toothpaste, and spillover effects of fluoridation from greater use of fluoridated water in the production of consumer goods.[24]

Because we focused on tooth loss as an outcome, a final limitation is that we did not capture the full range of impacts on oral health. For example, although the results suggest that the association between contemporaneous fluoride levels and tooth loss was not statistically significant, we cannot conclude there were no effects from exposure during adulthood because there may have been improvements in dental caries that did not result in tooth loss.[25] Therefore, by our sole focus on tooth loss, a choice primarily driven by data paucity, our results generally understate the overall impact of CWF on oral health.

Implications

Many studies have documented strong benefits from CWF exposure during childhood on a child's oral health,[5,24] but our evidence suggests that the benefits may be even larger than previously believed because prior studies may not have captured the full benefits from CWF. Furthermore, CWF appears to have led to a lasting improvement in racial and economic disparities in oral health. Lower-educated individuals and Blacks have seen disproportionate improvements when compared with higher-educated individuals and with Whites, respectively, which suggests that the "universal coverage" provided by CWF may have reduced disparities in oral health. ■

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Contributors

M. Neidell originated the study, conceptualized the study design, conducted the statistical analyses, and contributed to the development of the article. K. Herzog led the development of the article. S. Glied helped in originating the study, conceptualizing the study design, and editing the article.

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No institutional review board approval was required because the study did not involve contact with individual participants and did not collect confidential information.

References

1. Ast DB, Finn SB, McCaffrey I. The Newburgh-Kingston caries fluorine study; dental findings after three years of water fluoridation. *Am J Public Health.* 1950;40(6):716–724.
2. Heifetz SB, Horowitz HS, Driscoll WS. Effect of school water fluoridation on dental caries: results in Seagrove, NC, after eight years. *J Am Dent Assoc.* 1978;97(2):193–196.
3. Pizzo G, Piscopo MR, Pizzo I, Giuliana G. Community water fluoridation and caries prevention: a critical review. *Clin Oral Investig.* 2007;11(3):189–193.
4. Burt BA, Eklund SA. *Dentistry, Dental Practice, and the Community.* 5th ed. Philadelphia, PA: WB Saunders; 1999.
5. Griffin SO, Jones K, Tomar SLJ. An economic evaluation of community water fluoridation. *J Public Health Dent.* 2001;61(2):78–86.
6. Nanci A. *Ten Cate's Oral Histology Development, Structure and Function.* 7th ed. St Louis, MO: Mosby Elsevier; 2008.
7. Centers for Disease Control and Prevention. Achievements in public health, 1990–1999: fluoridation of drinking water to prevent dental caries. *MMWR Morb Mortal Wkly Rep.* 1999;48:933–940.
8. Tinanoff N. Use of fluoride. In: Berg J, Slayton R, eds. *Early Childhood Oral Health.* Ames, IA: Wiley-Blackwell; 2009.
9. Musacchio E, Perissinotto E, Binotto P, et al. Tooth loss in the elderly and its association with nutritional status, socio-economic and lifestyle factors. *Acta Odontol Scand.* 2007;65(2):78–86.
10. Sheiham A, Steele JG, Marcenes W, Tsakos G, Finch S, Walls AW. Prevalence of impacts of dental and oral disorders and their effects on eating among older people: a national survey in Great Britain. *Community Dent Oral Epidemiol.* 2001;29(3):195–203.
11. Eli I, Bar-Tal Y, Kostovetzki I. At first glance: social meanings of dental appearance. *J Public Health Dent.* 2001;61(3):150–154.

12. Glied S, Neidell M. The economic value of teeth. *J Hum Resour*. 2010;45(2)468–496.

13. Hyde S, Satariano W, Weintraub J. Welfare dental intervention improves employment and quality of life. *J Dent Res*. 2006;85(1):79–84.

14. Britten RH, Perrott GSJ. Summary of physical findings on men drafted in world war. *Public Health Rep*. 1941;56:41–62.

15. Klein H. Dental status and dental needs of young adult males, rejectable, or acceptable for military service, according to Selective Service dental requirements. *Milbank Mem Fund Q*. 1941;19(4):345–355.

16. US Census Bureau. *US Census of Population and Housing, 1990: Summary Tape File 3A*. Washington, DC: US Census Bureau; 1992.

17. US Census Bureau. *US Census Bureau, County and City Data Book: 2000*. Washington, DC: US Census Bureau; 2000.

18. US Census Bureau. *US Census Bureau, County and City Data Book: 1960*. Washington, DC: US Census Bureau; 1960.

19. US Census Bureau. *US Census Bureau, County and City Data Book: 1980*. Washington, DC: US Census Bureau; 1980.

20. Wooldridge J. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press; 2002.

21. Little RJA, Rubin DB. *Statistical Analysis With Missing Data*. New York, NY: John Wiley & Sons; 1987.

22. Singh KA, Spencer AJ, Armfield JM. Relative effects of pre- and posteruption water fluoride on caries experience of permanent first molars. *J Public Health Dent*. 2003;63(1):11–19.

23. *Oral Health in America: A Report of the Surgeon General*. Rockville, MD: US Department of Health and Human Services, National Institute of Dental and Craniofacial Research; 2000.

24. Horowitz HS. The effectiveness of community water fluoridation in the United States. *J Public Health Dent*. 1996; 56(5 spec no):253–258.

25. Griffin SO, Regnier E, Griffin PM, Huntley V. Effectiveness of fluoride in preventing caries in adults. *J Dent Res*. 2007;86(5):410–415.