Comparison of Two Methods of Estimating 48-month Tooth Loss Incidence

Gregg H. Gilbert, DDS, MBA; L. Scott Chavers, MPH; Brent J. Shelton, PhD

Abstract

Objectives: *This paper quantifies validity of self-reported tooth loss, compares incidence using two methods (semiannual self-report, biannual clinical examination), and compares conclusions about risk factors for tooth loss using these two methods.* ***Methods:*** *The Florida Dental Care Study included persons who at baseline had at least one tooth. In-person interviews and clinical examinations were conducted at baseline, 24 months, and 48 months, with semiannual telephone interviews in between.* ***Results:*** *Agreement between self-reported and clinically derived tooth loss was high, although some statistically significant differences by certain baseline characteristics were evident. On a nominal scale (some tooth loss, none), kappa was 0.88 and percent concordance was 94 percent. On a ratio scale, Spearman's correlation was 0.90. Using self-report, the incidence estimate would have been 34 percent, as compared to 36 percent based on clinical examination. In a single bivariate (loss by self-report, loss by clinical examination) multiple logistic regression, conclusions about statistical significance and magnitude of seven risk factors for tooth loss did not differ.* ***Conclusions:*** *Validity of self-reported incidence was excellent. The self-reported method allowed for semiannual estimates and was less resource intensive. Substantive conclusions about tooth loss using either method were similar, although validity did differ between persons with certain baseline characteristics.* *[J Public Health Dent 2002;62(3):163-69]*

Key Words: tooth loss, incidence, methods, validity, longitudinal studies.

Although US national studies suggest that the prevalence of edentulism is declining (1,2), tooth loss still occurs at substantial rates. Much like the fact that decline in activities of daily living (3) is a final common pathway for a broad range of decrements in general health, tooth loss constitutes a final common pathway for most dental diseases and conditions. This tooth loss can lead to substantial impacts on quality of life (4-6). In recognition of this impact, tooth loss is often used as a population's indicator of oral health, and its measurement often is used in national oral health monitoring (7-9). Because it is less resource intensive, tooth loss information typically is gathered by self-report, using standardized interviews. One noteworthy example is the United States National Health Interview Survey (10), which uses self-reported information to guide national health policy.

Some studies have documented the varying degrees of validity of participants' self-reported number of remaining natural teeth (as compared to the true number), using telephone, mail, and in-person (11-19) survey methods. However, these studies have all had a cross-sectional design, and to our knowledge, there have been no longitudinal studies of the validity of self-reported tooth loss. Furthermore, there has been no study that allowed longitudinal comparison of tooth loss estimates derived from self-reported methods as compared to tooth loss derived by direct clinical examination. This report does so. Additionally, the literature contains little information comparing the validity of self-reported tooth loss across important sociodemographic groups. This is despite the fact that certain groups, such as racial minorities and persons who reside in poor households, have been targeted increasingly in research designs because of their increased risk for disease.

The objectives for this report derive from these voids in the literature, using data from the Florida Dental Care Study (FDCS). One of the more important advantages of the FDCS is that it used a community-based sample of dentate adults (20) without regard to these adults' past dental care use. The FDCS also sampled adults from a diverse array of backgrounds. The overall objective of the FDCS was to develop a risk assessment model of longitudinal oral health outcomes. A key outcome of interest was tooth loss. Our objectives for this report are to quantify the validity of self-reported tooth loss during a longitudinal study of diverse adults, to compare tooth loss incidence estimates using two methods (semiannual self-report and biannual clinical examination), and to compare conclusions made about risk factors for tooth loss using these two methods.

Methods

Sample Development. Data were derived from the FDCS, which was a prospective longitudinal study of oral health and dental care. The goal of the sampling design was to ensure that a large number of persons at a hypothesized increased risk for oral health decrements would be included (namely, blacks, residents of rural areas, persons who were 45 years old or older, and the poor). Details of sampling methodology and selection are provided in an earlier publication (20). The 873 subjects who participated at baseline resulted in a sample of only

Send correspondence and reprint requests to Dr. Gilbert, Department of Diagnostic Sciences, University of Alabama, School of Dentistry, SDB Room 109, 1530 3rd Avenue South, Birmingham, AL 35294-0007. E-mail: ghg@uab.edu. Mr. Chavers is also with the Department of Diagnostic Sciences, School of Dentistry, and Dr. Shelton is with the Department of Biostatistics, School of Public Health, both at the University of Alabama at Birmingham.
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modest bias with respect to the population of interest (20). This sample had a dental care recency at baseline that was very similar to National Health Interview Survey (NHIS) data, and conclusions drawn from the FDCS and the NHIS regarding sociodemographic determinants of dental care recency were the same (20). Additionally, the percentage of the sample that had one or more dental visits in the first two years of the study, 77 percent, was similar to the figure, 75 percent, among the comparable group of 1989 NHIS respondents who reported having had one or more dental visits within the previous two years (10,21).

Although the study began at baseline from August 1993 to April 1994 with 873 participants, by 48 months 714 persons (unweighted *n*; weighted *n*=743) remained in the study, of whom 669 (unweighted *n*; weighted *n*=687) participated for the 48-month clinical examination of tooth status. To evaluate the potential for bias as a result of subject attrition, we compared characteristics of those who participated at 48 months for a clinical examination with those who did not. Persons who participated were more likely to have been regular dental care attenders, in better self-rated general health, white, free of severe loss of periodontal attachment at baseline (7 millimeters or more on at least one tooth), free of root fragments at baseline, free of severely mobile teeth at baseline, residents of rural areas, able to pay an unexpected $500 dental bill as reported at baseline, and to have had a household income at or above US $20,000 (chi-square tests and Mantel-Haenszel chi-square tests, $P<.05$). The mean (SD) number of teeth present at baseline among the 687 persons who participated through 48 months was 22.2 (7.0); for the nonparticipants, it was 21.3 (7.5). This difference was not statistically significant. No differences in participation were observed with respect to age group, sex, level of formal education, whether the participant was above the 100 percent or 150 percent poverty thresholds, presence of active dental caries at baseline, or whether they had dental insurance.

Data-gathering Stages. Subjects participated for a baseline in-person interview that was immediately followed by a clinical dental examination. The baseline interview queried a broad range of items having to do with past dental care utilization, attitudes toward dentists and dental care, numerous self-reported dental signs and symptoms, certain health-related habits, and financial and demographic circumstance. Self-reported items were elicited by asking a series of closed-ended questions that queried each item separately; that is, symptom checklists were not used. The questionnaire content and test-retest reliability of questions have been described previously (21-25), although for the sake of clarity the wording of some items will be reported here. The actual wording of all items can be found at the Internet site provided in the *Acknowledgments* section.

At baseline, participants were asked to describe their "approach to dental care" as: (1) "I never go to a dentist"; (2) "I go to a dentist when I have a problem or when I know that I need to get something fixed"; (3) "I go to a dentist occasionally, whether or not I have a problem"; or (4) "I go to a dentist regularly." For the purpose of this report, persons who responded #1 or #2 were classified as "problem-oriented attenders," and those who responded #3 or #4 were classified as "regular attenders." Participants also were asked to describe their self-rated general health: "At the present time, compared to others your age, how would you rate your general health? Would you say that your health is excellent, very good, good, fair, or poor?"

The clinical examination protocol, clinical diagnostic criteria, and interexaminer reliability have been described previously (26-28). Briefly, however, the examination recorded the presence and location of remaining teeth, root fragments (defined as missing more than three-fourths of the anatomic crown), bulk restoration fractures (missing, partly missing, or fractured amalgam, composite, or temporary fillings), fractured teeth involving the dental cusp and/or incisal edges (noncarious fracture more than 2 mm in occluso-apical or axial depth), severe root defects (noncarious defects more than 2 mm deep axially), teeth that were severely mobile (nonphysiologic occluso-apical movement or more than 2 mm buccolingual movement), and worst site per tooth regarding the periodontal attachment level relative to the cemento-enamel junction (CEJ). Attachment loss was calculated by subtracting the gingival recession measurement from the pocket depth measurement. For pocket depth, measurement was made from the crest of the gingival margin to the base of the sulcus or pocket. For recession, measurement was made from the CEJ to the crest of the gingival margin. If the crest was coronal to the CEJ, it was recorded as a positive number. If the crest was apical to the CEJ, recession was recorded as a negative number. Regarding the clinical examination measure most relevant for this report, interexaminer agreement at baseline was nearly perfect; all examiner pairings agreed on the number and location of teeth, with one exception: one examiner pairing disagreement for one examinee, upon which the presence of one tooth was disagreed.

The baseline interview and clinical examination were followed by a telephone interview at 6 months, 12 months, 18 months, 30 months, 36 months, and 42 months following the baseline. These interviews queried dental care use during the time since last interview, the types and number of services received, self-reported tooth loss ("Have you lost any teeth or had any teeth removed since we visited you about 6 months ago? [or talked with you on (date of previous interview)]"), how many and which teeth were lost, and the reason(s) that each tooth was lost.

At 24 months and 48 months after baseline, nearly all the interviews were done in person instead of by telephone, and this was followed by a clinical examination that was identical to the one done at baseline. At the 24-month stage, 46 interviews were actually done by telephone (because the participant refused to have a clinical examination or because the participant moved from the original FDCS counties, to an out-of-state location too distant to allow for an examination). One person had an in-person 24-month interview, but refused the clinical examination. At the 48-month stage, 66 interviews were actually done by telephone, because the participant refused to have a clinical examination (*n*=31); because the participant moved from the original FDCS counties to an out-of-state location too distant to allow for an examination (*n*=25); or because the participant be-

TABLE 1
Agreement Between Self-reported Tooth Loss and Tooth Loss Based on Clinical Examination from the Florida Dental Care Study at Baseline (1993–94), 24 months (1995–96), and 48 months (1997–98)*

Time Interval	Sample Size	Concordance (%)	Kappa	Sensitivity (%)	Specificity (%)	Predictive Value Positive (%)	Predictive Value Negative (%)
Baseline to 24 months	738	95	0.87	88	97	91	96
Baseline to 48 months	685	94	0.88	91	97	94	95

*Of necessity, this analysis is limited to persons who participated for both the interview and clinical examinations. Therefore, the sample size is reduced relative to the maximum self-reported tooth loss information available.

came edentulous by the 24-month examination, at which time full edentulism was verified clinically (n=10). For the 48-month time point, the mean (SD) number of months that the interview actually took place was 48.3 (0.8). We have previously described the financial and sociodemographic circumstance of the FDCS sample, its prevalence of dental conditions at baseline, and its incident dental care use (19-28).

Statistical Methods. Results were weighted using the sampling proportions to reflect the population in the counties studied, as described in detail previously (20). The only instance where unweighted numbers are used in this report relates to calculating attrition rates in the "Sample development" section earlier. All other numbers and percentages are weighted values.

Six measures of agreement were used (Table 1): (1) percent of pairs concordant; (2) the kappa statistic (29); (3) sensitivity; (4) specificity; (5) predictive value positive (PVP); and (6) predictive value negative (PVN). Percent concordance is the sum of the percentage of persons who either stated during the interview that they had lost one or more teeth since the previous clinical dental examination, and the clinical examination verified this; or stated that they did not have tooth loss and the examination verified this. The kappa statistic takes into consideration the amount of agreement that could be due to chance, and assigns a positive value for agreement that is better than by chance. We used an unweighted version of kappa. Generally, kappa values greater than 0.75 represent excellent agreement, while values between 0.40 and 0.75 represent fair to good agreement, and values less than 0.40 represent poor agreement (30).

Sensitivity was defined as the probability that the test method under study gives a positive finding when the validating criterion also gives a positive finding. In our context, this is the percentage of persons who had tooth loss since the previous clinical examination as measured by direct clinical examination, and who correctly reported having this tooth loss during an in-person or telephone interview.

Specificity was defined as the probability that the test method under study gives a negative finding when the validating criterion also gives a negative finding. In our context, this is the percentage of persons who did not have tooth loss since the baseline clinical examination, as measured by direct clinical examination, and who correctly reported so during all their interviews. PVP was defined as the probability that the test method under study is correct when it gives a positive finding, or the percentage of persons who reported tooth loss who actually did have tooth loss. PVN was defined as the probability that the test method under study is correct when it gives a negative finding, or the percentage of persons who reported not having tooth loss who actually did not have it.

All analyses were done using SAS (31). The chi-square test was used for bivariate comparisons when variables were nominal, and the Mantel-Haenszel chi-square trend test when variables were ordinal in scale (only relevant for findings reported in the "Sample Development" section). Comments about statistical significance refer to probabilities of less than .05.

Multiple regression analysis used the GENMOD procedure to do a single bivariate multiple logistic regression, where the two dichotomized measures of tooth loss (self-reported and clinically derived tooth loss after 48 months) were the outcomes of interest (i.e., bivariate). The intent of the regression analysis was to simulate how conclusions about risk factors for tooth loss might differ, depending upon whether tooth loss was measured by self-report or by clinical examination. The intent was to provide an example for method comparison, not to test a full range of predictors, which would not only have included person-level variables, but also would have included tooth-specific variables (e.g., as done in reference 32). This single bivariate multiple regression that appears in Table 2 correlated the error terms across the two tooth loss outcomes, which is necessary to avoid miscalculation of the parameter estimates and their standard deviations. This was possible after one of the authors (B.J.S.) created a SAS macro for use in the GENMOD procedure. This was also necessary to allow comparison across the two outcomes for the effects of individual predictors. This was in contrast to doing a separate univariate multiple logistic regression model for each of the two tooth loss outcomes, the error terms of which would not be correlated across equations, and which would preclude direct comparison of parameter estimate magnitudes.

Diagnostics to assess model goodness of fit and multicollinearity have been extended from linear regression to regression models for binary outcomes by Pregibon (33), and have been

TABLE 2
Bivariate Multiple Logistic Regression Model Comparing Odds Ratios of Baseline Predictors of Tooth Loss in the Florida Dental Care Study, Depending on Whether Incidence was Measured by Six-monthly Self-report or by Direct Clinical Examination at Baseline (1993–94) and 48 months (1997–98)

Potential Predictor Measured at Baseline	Loss of ≥1 Teeth during 48 Months' Follow-up			
	Based on Self-report		Based on Clinical Exam	
	OR	95% CI	OR	95% CI
Clinical examination factors				
Had severely mobile tooth	5.4	(2.5, 11.6)	8.6	(4.1, 18.3)
Had active dental caries	2.7	(1.6, 4.5)	2.7	(1.6, 4.6)
Had severe attachment loss	2.0	(1.2, 3.3)	2.0	(1.2, 3.4)
Had fewer than 25 teeth	1.5	(0.9, 2.5)	1.3	(0.8, 2.1)
Personal characteristics				
Approach to dental care	1.9	(1.1, 3.3)	1.9	(1.1, 3.2)
Race	1.1	(0.7, 1.9)	1.3	(0.8, 2.3)
Poverty status	1.1	(0.6, 1.7)	1.1	(0.6, 1.9)

n=632; deviance/df=1.21.
Coding of variables:
The outcome of interest was coded 1 if the participant lost one or more teeth during the 48 months of follow-up and 0 if not.
Had a severely mobile tooth: 1=participant had one or more severely mobile teeth at baseline, as judged by a clinical examiner; 0=did not.
Had active dental caries: 1=participant had one or more teeth at baseline with active dental coronal or root caries, as judged by a clinical examiner; 0=did not.
Had severe attachment loss: 1=participant had one or more teeth at baseline that had 7 or more millimeters of attachment loss, as judged by a clinical examiner; 0=did not.
Had fewer than 25 teeth: 1=participant had 1–24 teeth at baseline, as judged by a clinical examiner; 0=had 25–32 teeth.
Approach to dental care: 0=participant reported at baseline that he or she is a regular dental attender; 1=reported that he or she is a problem-oriented attender.
Race: participant reported race during the telephone screening interview as 0=white; 1=black.
Poverty status: 0=participant reported during the telephone screening interview that his/her household is at or above the 100 percent US poverty level, based on household size; 1=is below the 100 percent poverty level.

reviewed by Hosmer and Lemeshow (34). Pearson and deviance chi-square statistics were used to assess overall model fit. Multicollinearity was assessed using a procedure described by Belsley and colleagues (35), and which is available in the SAS REG procedure. No multicollinearity was observed. None of the models we fitted showed lack of fit, which would have been evidenced by a significant P-value associated with a "large" chi-square statistic.

Results

Validity of Self-reported Tooth Loss. Table 1 shows the agreement between self-reported tooth loss and tooth loss as determined by actual clinical examination. Using any of the six measures of agreement (which in this case is also a measure of validity), the validity of self-reported tooth loss at this nominal, "yes/no" level was very high.

We also compared validity across certain baseline characteristics. Differences in the values for validity, as measured by kappa, were not statistically significant between groups based on self-rated general health, sex, race, rural or urban area of residence, whether the participant graduated from high school, poverty status, typical approach to dental care (regular or problem-oriented attender), or whether the participant had at least 25 teeth at baseline. However, persons who were 45–64 years old at baseline had more valid reports (kappa=0.94; 95% confidence interval [CI]=0.90, 0.98) than did persons who were aged 65 years old or older at baseline (kappa=0.80; 95% CI=0.73, 0.87; P<.001).

Having quantified the validity of self-reported tooth loss on a nominal scale, we also quantified the correlation between self-reported and clinically derived tooth loss at the ratio scale. Self-reported tooth loss during the 48-month period ranged from 0 to 38. As a reminder, the maximum true number possible is 32, except in the most aberrant of cases. Spearman's correlation coefficient, r, was 0.90. When the analysis was limited to persons who lost at least one tooth, as judged by clinical examination, r was 0.83. Figure 1 shows a plot of the reported and clinically derived numbers of teeth. Once limited to persons who participated for the 48-month clinical examination, the mean (SD) tooth loss during the 48-month follow-up period by self-report was 1.1 (2.8); by clinical examination it was 1.1 (2.6). When persons who lost no teeth were excluded (based on clinical examination), these figures were 3.0 (3.7) by self-report; by clinical examination it was 3.1 (3.4).

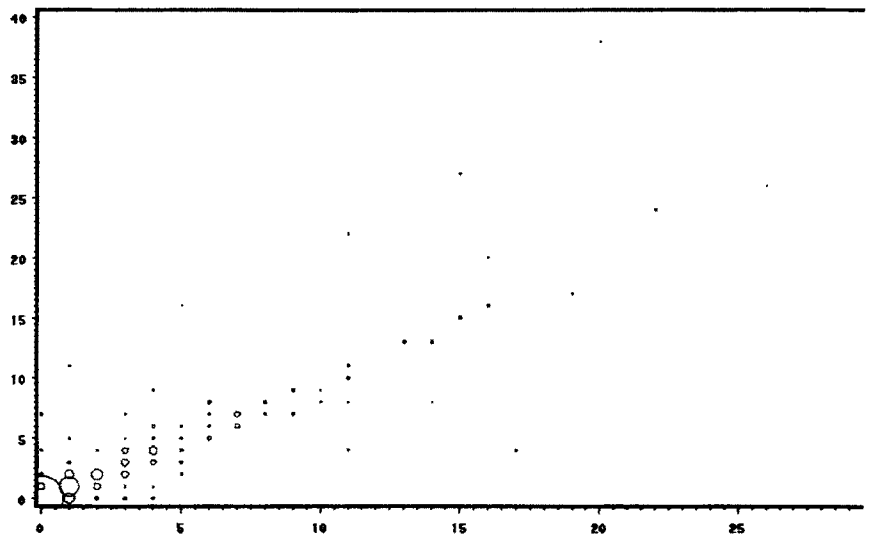
We also compared validity across certain baseline characteristics. Differences in the values for validity, as measured by Spearman's r, were not statistically significant between groups based on sex, race, rural or urban area of residence, poverty status, typical approach to dental care (regular or problem-oriented attender), or whether the participant had at least 25 teeth at baseline. However, persons who were 45–64 years old at baseline had more valid reports (r=0.95 [asymptotic standard error=0.01]) than did persons who were 65 years old or older at baseline (r=0.82 [asymptotic standard error=0.03]). Also, persons who had graduated from high school had more valid reports (r=0.92 [asymptotic standard error=0.02]) than did persons who had not graduated from high school (r=0.84 [asymptotic standard error=0.04]).

Comparison of Incidence Rates Using the Two Methods. Table 3 shows the incidence of tooth loss between baseline and 48 months after baseline. The semiannual incidence of self-reported tooth loss ranged from 5 percent to 9 percent. The cumulative self-reported tooth loss by 48 months was 34 percent, and was 36 percent when determined by actual clinical examination. Had the self-reported 48-month cumulative incidence been measured only using the information from those who also participated for

the 48-month clinical examination, the 48-month self-reported incidence would still have been 34 percent.

Risk Factors for Tooth Loss, by Method of Measurement. One of the objectives of the FDCS was to determine the risk factors for incident tooth loss, and for those that were significant, to estimate the magnitude of their effect. The regression model in Table 2 used potential risk factors as measured at baseline to predict tooth loss, in which the outcome was 48-month self-reported incidence or was based on clinical examination at 48 months. A comparison of each of the clinical factors and personal characteristics between the two outcomes revealed that each predictor that was statistically significant for one outcome was also significant for the other outcome. The odds ratios and their 95 percent confidence intervals were similar between the two outcomes, with one exception: whether or not the participant had a mobile tooth at baseline. However, the 95 percent confidence intervals for this risk factor do overlap, suggesting that the difference in magnitude was not statistically significant.

FIGURE 1
Plot Comparing Number of Teeth Lost Between the Florida Dental Care Study Baseline (1993–94) and 48-month Clinical Examinations (1997–98), as Measured by Self-report (Vertical Axis) and by Direct Clinical Examination (Horizontal Axis)



Discussion

We judge that the overall agreement statistics in Table 1 are quite high, and therefore conclude that self-reported tooth loss is of sufficient validity for most study requirements, when the study is of this design, when tooth loss is reported semiannually, and when that tooth loss is reported at the nominal, "yes/no" level. The magnitude of this validity did not differ by key base-

TABLE 3
Tooth Loss Incidence Between Baseline and 48 Months after Baseline in the Florida Dental Care Study, Based on Semiannual Self-report and Biannual Clinical Examinations from the Florida Dental Care Study at Baseline (1993–94), 24 months (1995–96), and 48 months (1997–98)

Characteristic (Weighted n and weighted %)	Telephone Interview 6-month	Telephone Interview 12-month	Telephone Interview 18-month	24-month In-person Interview or Clinical Exam	Telephone Interview 30-month	Telephone Interview 36-month	Telephone Interview 42-month	48-month In-person Interview or Clinical Exam
Number of persons participating for interview, hence who self-reported on tooth loss	854	825	817	787	771	764	744	742
Number (%) of persons with self-reported loss of ≥1 teeth	75 (9%)	50 (6%)	70 (9%)	59 (8%)	57 (7%)	39 (5%)	40 (5%)	60 (8%)
Cumulative number (%) of persons with self-reported loss of ≥1 teeth, excluding only those who did not participate at current interval	75 (9%)	107 (13%)	152 (19%)	172 (22%)	200 (26%)	220 (29%)	235 (32%)	256 (34%)
Number of persons participating in clinical examination	—	—	—	739	—	—	—	686
Cumulative number (%) of persons with loss of ≥1 teeth, based on clinical examination	—	—	—	176 (24%)	—	—	—	246 (36%)

line characteristics, with the exception of age group. In a post hoc analysis, we stratified age group agreements by self-rated general health. After this stratification, the differences in validity by age group were no longer statistically significant. This circumstance suggests a possible explanation for why older adults had poorer validity of self-reported tooth loss.

To our knowledge, there are no extant dental studies that have assessed validity of self-reported tooth loss longitudinally, nor any that have assessed differences in the substantive conclusions made from self-reports and clinical examinations. Our analysis of the cross-sectional literature in an earlier report of our cross-sectional findings from the FDCS suggested that findings from the FDCS sample had much in common with the previous literature. Therefore, we have no reason to suspect that our longitudinal findings would be aberrant in any way.

One limitation of this study design is that we cannot delineate an effect due to mode of questionnaire administration (telephone or in-person). Previous analysis from the FDCS suggested statistically higher probabilities of reporting events when the in-person mode was used (36). We also are not able to delineate how much our estimation of validity and incidence were affected by nonrandom attrition. Given that older persons were less likely to have remained in the study and had less valid reports, our estimation of validity may be an overestimate.

Our previous analyses of cross-sectional data from this sample (19) suggested that self-reported tooth counts were not consistently valid when participants were asked to report an actual number of teeth, instead of simply whether or not they had teeth. However, this current report of incident tooth loss suggests that the validity of self-reported incidence is high, with r=0.90. Nonetheless, differences in the correlation between age groups and levels of formal education suggest that differences in validity may affect group comparisons. Furthermore, we did not quantify tooth-specific validity, which would require an even greater level of specificity by the participant.

The questionnaire used in this report did not inform participants that the maximum possible number of teeth was 32. One participant reported that a total of 38 teeth had been lost throughout the follow-up period of 48 months. No other participants reported more than 27 teeth lost. The largest number reported in any single six-month interview was 18 teeth. We judge that future studies should provide participants with this number in an effort to improve the validity of self-reports, as well as inform participants that the maximum in any single maxillary or mandibular arch is 16. We have reported previously that some persons who lost coronal tooth structure during follow-up may have reported incident tooth loss because they concluded that the tooth was lost, although in fact the tooth root remained (37).

Two advantages of the self-reported method can be gleaned from Table 3. The first advantage is that more persons will participate for an interview than will for the clinical examination. The second advantage is that semiannual estimates of tooth loss can be obtained, instead of having to rely on biannual determinations.

Our quantification of validity notwithstanding, we conclude that our comparison of the two methods, as distinct from validity assessment, has greater implications for research methodology. Most studies will use either one or the other method, not both. Therefore, we judge that the most relevant discussion has to do with how the substantive conclusions differ, if at all, depending upon which method is used. That question is addressed by results in Table 2. The results in this table suggest that the substantive conclusions would have been the same using either method. Although the point estimates and confidence intervals in Table 2 are largely the same for all predictors except for "mobile tooth," misclassification from self-report would bias the odds ratio toward the null. This, indeed, was the case, with an odds ratio of 5.4, compared to an odds ratio of 8.6 based on clinical examination. The self-reported method offers the advantages of being able to obtain semiannual estimates and being less resource intensive. A higher participation rate may be achieved with the self-reported method; however, because the validity of self-reports is not perfect and therefore results in a larger standard error for group comparisons, a greater sample size would be required to offset this effect.

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The opinions and assertions contained herein are those of the authors and are not to be construed as necessarily representing the views of the University of Alabama at Birmingham or the National Institutes of Health. The informed consent of all who participated in this investigation was obtained after the nature of the procedures had been explained fully. An Internet home page devoted to details about the FDCS can be found at http://nersp.nerdc.ufl.edu/~gilbert/ (formerly at http://www.nerdc.ufl.edu/~gilbert/).

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