# Type 1 Diabetes Mellitus and Oral Health: Assessment of Tooth Loss and Edentulism

**Paul A. Moore, DMD, PhD; Robert J. Weyant, DMD, DrPH; Mary Beth Mongelluzzo, RDH, MS; Daniel E. Myers, DMD, MS; Karen Rossie, DDS, MS; James Guggenheimer, DDS; Heidi Hubar, DMD, MPH; Harvey M. Block, DMD; Trevor Orchard, MBBCh, M Med Sci**

## Abstract

***Objective:*** *The oral health of an adult population previously diagnosed with juvenile onset insulin dependent-diabetes was comprehensively assessed. The goal of this exploratory cross-sectional evaluation was to describe the characteristics related to partial tooth loss and edentulism in subjects with Type 1 diabetes mellitus.* ***Methods:*** *An adult population of 406 Type 1 diabetes mellitus subjects, who had been monitored for 6–8 years as part of a University of Pittsburgh longitudinal study of medical complications associated with diabetes, received an oral health examination for missing teeth, edentulism, coronal and root caries, periodontal status, and oral health behaviors.* ***Results:*** *Of the 406 subjects evaluated, 204 had no missing teeth, 186 had partial tooth loss (1–27 missing teeth), and 16 were edentulous. Patients who had partial tooth loss or who were edentulous were generally older; had lower incomes and levels of education; and had higher rates of nephropathy, neuropathy, retinopathy, and peripheral vascular disease. A logistic regression model found partial tooth loss to be significantly associated with extensive periodontal disease in remaining teeth (OR=7.35), a duration of diabetes longer than 24 years (OR=5.32), not using dental floss (OR=2.37), diabetic neuropathy (OR=2.29), household income less than $20,000 (OR=2.21), multiple coronal caries and fillings (OR=1.98), and bleeding on probing (OR=1.82).* ***Conclusions:*** *Although the majority of these adult Type 1 diabetes patients had serious medical complications associated with their diabetes, the possible impact of diabetes mellitus on oral health should be included in their overall management. [J Public Health Dent 1998;58(2):135-42]*

*Key Words: IDDM, Type 1 diabetes mellitus, insulin, tooth loss, edentulousness, oral health.*

Diabetes mellitus is a chronic metabolic disorder that effects approximately 4 million to 12 million people in the United States and probably 100 million people worldwide. It is the sixth leading underlying cause of death in the United States and has been estimated to cost 91.5 billion dollars annually in medical costs and lost productivity (1). Medical complications associated with diabetes include renal disease, retinopathy, neuropathy, peripheral vascular disease, and coronary heart disease (2,3). Reported oral health complications associated with diabetes that can be encountered by dental practitioners include xerostomia, tooth loss, gingivitis, periodontitis, odontogenic abscesses, and soft tissue lesions of the tongue and mucosa (4-6).

The prevalence and characteristics of oral health complications may be dependent on the specific type of diabetes. Diabetes is commonly categorized as insulin-dependent diabetes mellitus (IDDM) and noninsulin-dependent diabetes mellitus (NIDDM). Approximately 10 percent to 20 percent of all diabetic patients are insulin dependent or Type 1. These patients usually have rapid onset of symptoms and are characterized by a virtual complete inability to produce insulin. Nearly 90 percent of IDDM patients are diagnosed before the age of 21. NIDDM or Type 2 diabetes is the most common type of diabetes, is often associated with obesity, and is characterized by slow onset of symptoms, usually after 40 years of age. Other less prevalent forms of diabetes include gestational diabetes seen during pregnancy and diabetes secondary to other medical conditions (2).

Overall rates of complete and partial tooth loss have been decreasing in the United States for the past several decades. Even as life expectancy increases, it is now generally believed that loss of the natural dentition is not an inevitable consequence of aging (7,8). Although the prevalence of tooth loss is apparently decreasing in the general population, variations in subgroups do occur and may indicate special considerations and management by the dental profession. In this regard, the impact of diabetes on medical and oral health as well as the goals of disease prevention, are addressed in "Healthy People 2000" (9). The health goals established in this national consensus publication specify that the direction for research and future care be focused on decreasing mortality associated with diabetes, decreasing medical complications, and preventing the oral health sequelae in this special population.

The association of diabetes with tooth loss is generally accepted (2,10-14). Although some early reports suggested both increases and decreases in caries rates, larger surveys of diabetic populations seem to indicate that caries rates are not elevated (11,15). Gin-

Send correspondence and reprint requests to Dr. Moore, 614 Salk Hall, University of Pittsburgh, School of Dental Medicine, Pittsburgh, PA 15261. E-mail: PAM7@pitt.edu. Drs. Weyant, Mongelluzzo, Hubar, and Block are with the Department of Dental Public Health, School of Dental Medicine; and Drs. Myers, Rossie, and Guggenheimer are with the Department of Oral Medicine and Pathology, School of Dental Medicine; all at the University of Pittsburgh. Dr. Orchard is with the Graduate School of Public Health, Department of Epidemiology, University of Pittsburgh. Support provided by NIH contract NIH-NIDR-1-91-R4 and grant R01-DK34818. Preliminary report presented at the 1995 IADR annual meeting. [J Dent Res 1995;74(Spec Iss):1314.] Manuscript received: 5/2/96; returned to authors for revision: 10/4/96; accepted for publication: 3/27/98.

givitis is reported in younger populations and periodontitis with loss of attachment is reported in adults (13,14,16-19). The frequency and severity of periodontal disease may be associated with the duration of their disease (20). The periodontal health of Type 2 diabetic patients has been evaluated extensively in the Pima Indian population in Arizona, where diabetic status has been significantly associated with attachment and bone loss (10). Periodontitis in younger Type 1 diabetic patients has not been reported consistently (21,22). Reported oral health differences between Type 1 and Type 2 patients may relate to differences in glycemic control strategies, age, tobacco use, duration of disease, or periodontal disease susceptibility. The consequences of dental diseases and subsequent tooth loss are not only important considerations for the quality of life of a diabetic patient, but can significantly impact on overall health by compromising a patient's ability to maintain a healthy diet and proper glycemic control.

An ongoing epidemiology study at the University of Pittsburgh has been thoroughly evaluating the medical status of a large population of Type 1 diabetes mellitus patients. An oral health study team at the University's School of Dental Medicine had an opportunity to perform a comprehensive oral health evaluation of these patients. The goal of this exploratory cross-sectional evaluation was to describe the characteristics related to partial tooth loss and edentulism in subjects with Type 1 diabetes mellitus.

## Methods

**Research Design.** The Type 1 diabetic subjects enrolled in this oral health study were participants of the ongoing University of Pittsburgh Epidemiology of Diabetes Complication Study (EDC). This cohort was derived from the Children's Hospital of Pittsburgh registry of early onset diabetes (<17 years of age) and is representative of the local residents within Allegheny County diagnosed with Type 1 diabetes (23). Eligible cases for the EDC cohort were patients diagnosed between 1/1/50 and 5/31/80 who lived within 100 miles of Pittsburgh. Of 979 eligible subjects, 788 (80%) provided questionnaire data and 658 (67%) received medical examinations at baseline (1986–88). At two-year intervals since baseline, the EDC continues to provide medical examinations to determine the incidence of retinopathy, nephropathy, neuropathy, and cardiovascular disease within this cohort.

All subjects scheduled for their regular two-year examination for the EDC study were contacted by members of the University of Pittsburgh Oral Health Science Institute, informed of the purpose of the oral health evaluation, and asked to participate. All subjects were recruited and examined between March 1992 and August 1994. Questionnaires requesting medical and dental histories, oral health behaviors, and psychosocial information were mailed to the subjects prior to the appointment. Appointments for the exams were scheduled between 7:00 and 11:00 AM on Wednesday and Saturday mornings. Subjects were asked to have nothing to eat or drink after midnight prior to their appointment if possible. Upon arrival, their questionnaires were checked and an IRB approved consent form was presented and signed.

The oral health examination was performed in a separate room equipped with a portable dental chair (A-Dec model 3460) and an MDT Rolex side mount dental examination light. Initially, subjects had urine and blood samples collected, had their blood pressure recorded, received their normal insulin injection and breakfast. Following breakfast, a full mouth coronal and root caries exam and a split mouth periodontal exam were performed by one of two trained dental examiners. These dentists were provided instructions for performing periodontal probings and caries assessments. Training and calibration sessions for both the caries and periodontal exams were provided prior to the initiation of the study and periodically during the two years of data collection. Subjects at risk for bacterial endocarditis were excused from the periodontal probing assessments. Specific results of the periodontal, caries, and saliva assessments are to be published separately. The sequence for all oral health assessments required approximately 25 minutes. Participants of the oral health exam were reimbursed $20.00 at the end of the appointment.

Following the oral health examination, the subjects underwent EDC assessments for possible medical complications of diabetes. These assessments included a physical examination; an EKG; an additional urine sample; and an evaluation of renal, neural, retinal, and cardiovascular functions (see specific methods below).

**Oral Health Assessment Methodology.** During the initial interview, demographic data, medical histories, and dental histories were reviewed. Demographic data included age, sex, weight, height, race, education, marital status, and income. Patient histories solicited information regarding current medical care, medications, hospitalizations, significant medical histories (hepatitis, epilepsy, etc.), allergies, cardiac murmurs and/or valve surgery, prosthetic hip replacements, and pregnancy, as well as information regarding dental care, most recent visits to the dentist, oral hygiene habits (use of fluoride toothpaste, frequency of brushing and flossing), community water fluoridation, perceived treatment needs, and dental insurance. Published and validated questions regarding dental anxiety (Dental Anxiety Scale) and xerostomia (subjective xerostomia questionnaire) also were included (24,25). Additionally, subjects were requested to report their household income (within $10,000 increments) and their highest level of education.

Subjects were questioned regarding their use of tobacco products. Inquiries included use of chewing tobacco, as well as current and lifetime history of cigarette use (start age, duration, consumption). Total weekly alcohol consumption was determined from a questionnaire. Weekly consumption estimates were requested for tea and coffee; regular, diet, and caffeine-free soft drinks; as well as beer, wine, and mixed drinks/liquor. Data for weekly wine, beer, and liquor consumption were summed to provide an estimate of weekly alcohol consumption (ounces per week).

All missing teeth excluding third molars were recorded. The likely cause of loss was distinguished between extraction due to dental diseases or due to orthodontic treatment. Agreement for tooth loss measurements between the two examiners during the calibration sessions was 100 percent.

Coronal caries was diagnosed for pit and fissure lesions on occlusal, buccal, and lingual surfaces and smooth surface lesions on buccal, lingual, and proximal surfaces. Criteria for caries detection as well as special conditions (e.g., crowns, banded teeth, sealants) were identical to those established by the NIDR Adult Study (26). During the initial calibration sessions, the mean percent agreement for decayed and filled surfaces between the two examiners was determined to be 95.9 percent and the kappa statistics ranged from .867 to .922.

Periodontal assessments were made on two randomly designated quadrants: maxillary left/mandibular right or maxillary right/mandibular left. For bleeding on probing measures, the probe was gently inserted to no more than 2 mm into the gingival sulcus. Bleeding on probing was assessed as present or absent for each tooth examined. Supragingival calculus on each tooth was rated as present or absent based on visual assessments. Attachment levels and pocket depths were measured using a standard CPITN pressure controlled probe graduated with 2, 4, 6, 8, 10, and 12 millimeters. Third molars were excluded from the exam. Using methods described by the NIDR Adult Survey, three sites on the buccal/facial surface of each tooth (mesial, mid-cervical, and distal) were probed. Measurements from the gingival crest to the cementoenamel junction and the base of the pocket were made. Interexaminer correlation coefficients for loss of attachment (LOA) were determined prior to the study to range from .813 to .832 for mesial, .688 to .785 for cervical, and .645 to .832 for distal probing measures. Mean estimates for the two examiners were 0.93 (SE=.08 mm) and 0.94 (SE=.07 mm).

**Assessment of Diabetic Complication.** As previously described by Orchard et al. (3,27,28), diabetes complication measures and risk factors studied by the EDC included glycemic control, nephropathy, neuropathy, retinopathy, and peripheral vascular disease.

*Glycemic Control.* Fasting blood samples were used to assay glycosylated hemoglobin (%A1) and blood glucose. A dichotomy was established based on the median value for the total EDC cohort when first enrolled in 1986–88. The criteria of less than 10.1%A1 was considered fair to good glycemic control, and values equal to or greater than 10.1%A1 were considered poor glycemic control. Blood glucose determinations were reported as mg/100 ml.

*Nephropathy.* Overt nephropathy was defined as albumin excretion rates (AER) greater than 200 gm/min in two of the three timed urine samples or in the absence of urine collections, serum creatinine >180 M (2 mg/dl). Microalbuminuria was defined as an AER between 20 and 200 gm/min in two of three of the urine samples. In a few subjects, the adequacy of the timed urine samples was questionable in terms of creatinine excretion. In these cases, a previously validated albumin-creatinine urinary ratio was used (29). Renal failure (dialysis and/or status post-kidney transplant) was categorized separately. Four categories (no nephropathy, microalbuminuria, overt, and renal failure) were established by the EDC investigators.

*Neuropathy.* Distal symmetrical polyneuropathy (DSP) was determined according to the clinical exam component of the DCCT protocol (30) and considered present if, in the opinion of the examining physician, at least two of the following three criteria were present and not due to a nondiabetic cause: symptoms consistent with DSP, decreased (i.e., requiring reinforcement) or absent tendon reflexes, and signs of sensory loss. Three categories (none, probable, and definite) were used for the assessment.

*Retinopathy.* Stereoscopic fundus photographs were taken of fields 1, 2, and 4 with a Zeiss camera and were read by the Fundus Photography Reading Center, University of Wisconsin-Madison. Readings were classified according to the modified Airlie House system and grouped into four categories: no retinopathy (grade 10 in both eyes), early background retinopathy (highest grade in either eye of 20 or 30), advanced background retinopathy (highest grade of 40 or 50), and proliferative retinopathy (grade 60 or greater in at least one eye).

*Peripheral Vascular Disease (PVD).* Lower extremity arterial disease was assessed by comparing ankle and arm blood pressures. An ankle-arm blood pressure ratio <0.8 at rest or a history of amputation were categorized as positive. Calcification (i.e., ankle pressure >75 mm Hg above arm pressure) also was identified. Two categories were used in the analysis: absent or present.

**Data Management and Analyses.** All data were initially screened for accuracy and completeness. Data were coded prior to computer entry using Key Entry III software and entered twice to verify accuracy of entry. A further check was provided by review of frequency data of each entered file. Data were transferred to a Digital Equipment Corporation VAX/VMS mainframe computer via the System 1032 Database Management System (Software House, Cambridge, Massachusetts). EDC and oral health files were then merged and converted to SAS format for creation of summary variables. Final analysis was carried out using a Macintosh Power PC and JMP software (Version 3.1, SAS Institute Inc., Cary, NC).

Differences in the rates of partial and complete tooth loss for various factors were summarized initially and compared using ANOVAs for continuous variables and chi-square tests for categorical variables. Because the number of teeth lost for these subjects was not normally distributed, tooth loss was divided into categories of "no tooth loss" or "one or more tooth loss" (excluding orthodontic extractions). This tooth loss dichotomy was used as the dependent variable to develop a nominal logistic regression model.

Independent variables were created by dichotomizing the continuous and categorical variables based on median values or on clinically relevant cut points. The variables so created were: age (greater than the median age of 32 years), sex, household income (less than $20,000), education (high school or less), currently smoking cigarettes, having ever smoked cigarettes, having ever chewed tobacco, alcohol consumption (greater than 7 ounces per week), toothbrushing (one or fewer times a day), use of dental floss, use of fluoride toothpaste, currently living in a community with fluoridated water, having visited a dentist in the last 12 months, presence of xerostomia symptoms (positive response to one or more xerostomia questions), dental anxiety (Dental Anxiety Scale greater than 8), supragingival calculus (present or absent), bleeding on probing (greater than median value), extensive periodontal disease (10% or more of the sites examined having greater than 3 mm loss of attachment), coronal caries (mean DFS per tooth of 1.0 or more),

**TABLE 1**
**Population Demographics for Diabetic Subjects by Tooth Loss Category**

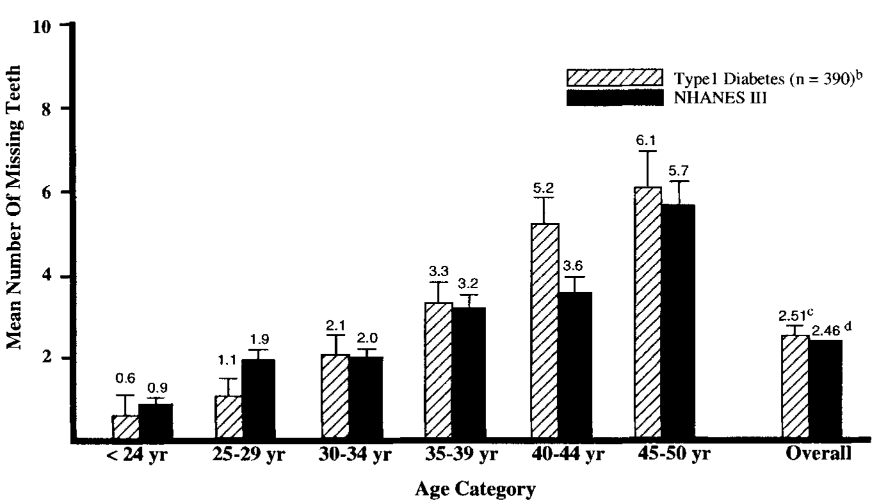
| | Tooth Loss Category | | | |
|---|---|---|---|---|
| | None | Partial | Complete | Total |
| Sex | | | | |
| No. of males | 103 | 96 | 5 | 204 |
| No. of Females | 101 | 90 | 11 | 202 |
| Total | 204 | 186 | 16 | 406 |
| Age categories | | | | |
| No. <24 years | 51 | 14 | 0 | 65 |
| No. 25–29 years | 56 | 26 | 0 | 82 |
| No. 30–34 years | 51 | 42 | 5 | 98 |
| No. 35–39 years | 32 | 49 | 1 | 82 |
| No. 40–44 years | 9 | 36 | 1 | 46 |
| No. >45 years | 5 | 19 | 9 | 33 |
| Total | 204 | 186 | 16 | 406 |
| Age | | | | |
| Mean years ±SE (range) | 29±0.5 (14.2–51.2) | 35.9±0.5 (13.9–50.8 | 42.2±1.8 (30.0–52.8) | 33.0±0.4 (13.9–52.8) |
| Household income* | | | | |
| Percent <$20,000 | 13.8 | 32.4 | 64.3 | 24.3 |
| Education | | | | |
| Percent ≤high school | 24.0 | 38.7 | 37.5 | 31.3 |

*Incomplete reporting of income (*n*=378).

**TABLE 2**
**Distribution of Missing Teeth per Subject**

| Missing Teeth per Subject | No. of Subjects | Total (%) |
|---|---|---|
| 0 | 204 | 50 |
| 1–3 | 120 | 30 |
| 4–10 | 41 | 10 |
| 11–21 | 21 | 5 |
| 22–27 | 4 | 1 |
| 28 (edentulous) | 16 | 4 |
| Total | 406 | 100 |

**FIGURE 1**
**Prevalence of Tooth Loss by Age Category***
**[The hashed bars illustrate mean total number of missing teeth at various age ranges and overall for dentate diabetic subjects (*n*=390). The overall NHANES III estimate is age adjusted. Overall diabetes rate is not significantly different than NHANES value. Extractions for orthodontic treatment were not excluded to permit comparison with published NHANES III findings: Table 5, white non-Hispanic ethnicity (27).]**




[a] extractions for orthodontic reasons included
[b] edentulous patients excluded
[c] n.s. compared to NHANES III adjust rate of 2.46
[d] age adjusted mean tooth loss

root caries (any DFS present), duration of disease (longer than median age of 24 years), glycosylated hemoglobin (characterized by the EDC as poor), nephropathy (ratings of overt and renal failure), neuropathy (rating of definite), retinopathy (ratings of advanced or proliferative), and peripheral vascular disease (rating of present).

Crude odds ratios were calculated for all possible variables associated with tooth loss. Initially, a model that excluded dental variables was created to permit inclusion of edentulous subjects and subjects who could not be provided a periodontal exam because of a risk of bacteremia. All potentially significant covariates ($P<.20$) were entered in the models. Variables were sequentially omitted in developing the models based on a $P<.05$ criterion. Then, all variables entered initially were reentered individually to ensure that they were appropriately excluded with the descending stepwise procedure. Finally, possible interactions of variables significant in the final model were evaluated. Goodness of fit was evaluated using the loglikelihood and chi-square statistic.

## Results

During this study, the oral health collaborative team contacted by mail all 412 subjects who were scheduled for their EDC appointments and enrolled 406 Type 1 subjects who agreed to participate (Table 1). The 406 subjects had a mean age of 33.0 (SE=0.40) years and a mean age at onset of Type 1 diabetes mellitus of 8.4 years. The 204 males and 202 females examined were primarily (98%) white non-Hispanics. Of the 406 total subjects, 186 subjects (45.8%) had partial tooth loss

(1–27 missing teeth) and 16 subjects (3.9%) were edentulous. The distribution of missing teeth per subject is delineated in Table 2.

Figure 1 illustrates the mean number (SE) of missing teeth for age categories of both the diabetic subjects and data reported by NHANES III for white non-Hispanics (8). To permit comparison, the diabetic subject data include tooth lost for orthodontics and exclude the 16 subjects who were edentulous. Thirty percent of the subjects in the age range of 35-44 years had all 28 teeth. The overall mean number of teeth lost per diabetic subject (2.51, SE=.23) was not significantly greater than the age-adjusted NHANES III survey findings of 2.46 (student's T-test=.2142, $P$=.584). Similarly, the edentulous rate of 3.94 percent for the diabetic subjects was not significantly greater than the age-adjusted white non-Hispanic NHANES III rate of 2.74 percent (chi-square=1.936, $P$=.163).

The mean duration of diabetes for all the diabetic subjects was 24.6 years (SE=.38), while the mean glycosylated hemoglobin levels was 11.0 percent (SE=.09). The prevalence rates of diabetic complications, as assessed by the EDC at the time of our oral health examination, were 44.3 percent for advanced or proliferative retinopathy, 23.4 percent for overt nephropathy or renal failure, 27.1 percent for definite peripheral neuropathy, and 10.8 percent for definite peripheral vascular disease.

The 16 edentulous diabetic subjects were older (42.2 years, SE=1.8), had a longer duration of disease (32.3 years, SE=2.1), higher glycosylated hemoglobin level (12.0%, SE=.49), and were found to have more diabetic complications: 75.0 percent reporting advanced or proliferative retinopathy, 56.3 percent reporting overt nephropathy or renal failure, 50.0 percent reporting definite peripheral neuropathy, and 43.8 percent reporting definite peripheral vascular disease.

The crude odds ratios of variables possibly associated with tooth loss ($P$<.20) that were used for the logistic regression analysis are provided in Table 3. They included: age, household income, education, currently smoking cigarettes, having ever smoked cigarettes, alcohol consumption, supragingival calculus, bleeding on probing, extensive periodontal disease, coronal caries, root caries, use of fluoride

**TABLE 3**
**Odds Ratios for Variables Associated with Missing Teeth**

| Variable Name | $n$ | % Tooth Loss | Odds Ratio | 95% CI | $P$-value |
|---|---|---|---|---|---|
| Subject demographics | | | | | |
| Age (>32 years) | 207 | 68.1 | 4.83 | 3.19, 7.40 | <.0001 |
| Household income* (≤$20,000) | 92 | 71.7 | 3.31 | 2.01, 5.60 | <.0001 |
| Education (≤high school) | 127 | 61.4 | 1.99 | 1.30, 3.06 | .0017 |
| General health habits | | | | | |
| Cigarette smoking now (yes) | 78 | 67.9 | 2.55 | 1.52, 4.35 | .0004 |
| Cigarette smoking history (never smoked) | 254 | 40.9 | 2.61 | 1.73, 3.99 | <.0001 |
| Alcohol consumption* (≥7 oz/wk) | 193 | 53.9 | 1.39 | 0.94, 2.07 | .0997 |
| Dental disease and oral health behaviors | | | | | |
| Supraginigival calculus (present) | 44 | 59.1 | 2.01 | 1.06, 3.89 | .0348 |
| Bleeding on probing*† (infrequent) | 172 | 48.2 | 1.51 | 0.96, 2.36 | .0700 |
| Extensive periodontal disease*† (≥10% LOA≥4 mm) | 34 | 82.4 | 7.04 | 3.01, 19.30 | <.0001 |
| Coronal caries† (DFS/tooth<1) | 245 | 38.8 | 2.66 | 1.74, 4.08 | <.0001 |
| Root caries† (DFS/tooth=0) | 327 | 44.7 | 2.16 | 1.24, 3.81 | .0069 |
| Toothbrushing† (≥once a day) | 283 | 44.9 | 1.58 | 1.02, 2.45 | .0702 |
| Use of dental floss† (yes) | 267 | 41.9 | 2.39 | 1.57, 3.68 | .0008 |
| Use of fluoride toothpaste*† (yes) | 294 | 47.6 | 2.90 | 0.97, 10.6 | .1924 |
| Currently living with fluoridated water*† (yes) | 135 | 51.1 | 1.22 | 0.75, 1.99 | .4227 |
| Visited dentist in last year† (yes) | 269 | 45.4 | 1.49 | 0.98, 2.27 | .1680 |
| Xerostomia symptoms* (none) | 300 | 45.3 | 2.07 | 1.31, 3.30 | .0020 |
| Dental anxiety* (CAS>8) | 151 | 56.9 | 1.67 | 1.11, 2.51 | .0145 |
| Diabetes variables and complications | | | | | |
| Duration of IDDM (>24 years) | 201 | 70.2 | 5.55 | 3.65, 8.54 | <.0001 |
| Retinopathy (advanced or proliferative) | 180 | 63.9 | 2.83 | 1.89, 4.25 | <.0001 |
| Nephropathy (overt or failure) | 95 | 63.2 | 2.04 | 1.28, 3.30 | .0031 |
| Neuropathy (definite) | 110 | 72.3 | 3.80 | 2.38, 6.21 | <.0001 |
| Peripheral vascular disease (present) | 44 | 68.2 | 2.37 | 1.24, 4.74 | .0114 |

*Incomplete reporting.
†Edentulous subjects excluded from bivariate analysis.

toothpaste, visit to the dentist, toothbrushing, not using dental floss, xerostomia symptoms, dental anxiety, duration of disease, retinopathy, nephropathy, neuropathy, and peripheral vascular disease. For these bivariate analyses, dental variables (i.e., coronal caries, etc.) were evaluated initially only in dentate subjects ($n$=390).

Results from the initial logistic model, which did not include dental variables, determined that missing teeth were associated with longer duration of diabetes (OR=3.86, 95% CI=2.10, 7.21), household income less than $20,000 (OR=3.06, 95% CI=1.73, 5.51), current cigarette smoking (OR=2.04, 95% CI=1.11, 3.83), age older than 32 years (OR=1.90, 95% CI=1.02, 3.49), and education level (OR=1.81, 95% CI=1.09, 3.05).

The final logistic model of factors associated with missing teeth in our Type 1 diabetic mellitus subjects is presented in Table 4. A total of 299 subjects had complete data available on all variables used to create the final regression model. Of these, 141 (44%) had partial tooth loss. The inclusion of dental variables excludes the 16 edentulous subjects. Periodontal evaluations were not performed on 68 subjects reporting to be at risk for bacteremias. Incomplete reporting of income and visits to the dentist accounted for the remaining 23 subjects lost to the analysis. No interactions terms entered the final model. A loglikelihood goodness-of-fit test ($P$=.271) suggests that a logistic regression was appropriate to model these data. The final regression model found tooth loss to be significantly associated with extensive periodontal disease in remaining teeth, a duration of diabetes longer than 24 years, not using dental floss, diabetic neuropathy, household income less than $20,000, multiple coronal caries and fillings, and bleeding on probing (Table 4).

## Discussion

The duration of diabetes was associated with tooth loss in this diabetic population. Because Type 1 has a rapid onset, it rarely exists undiagnosed. The current population, restricted to juvenile onset diabetes, had a mean onset age of 8.4 years and a duration of disease of 24.6 years. The age in this Type 1 diabetes population therefore is highly correlated with duration of disease (r=.868), as well as other factors such as extensive periodontal disease, caries, and neuropathy. That age was a factor in the initial model that did not include dental variables, but did not enter into the final model, suggests that dental diseases such as periodontal disease and caries contribute substantially in explaining the consequences of aging in this adult population. Similarly, current use of cigarettes was associated with missing teeth in the initial model, but not the final model. That smoking did not enter into the final model when dental variables, including periodontal diseases, were included may support previous findings that smoking promotes periodontal disease and consequently loss of teeth (17,18).

Because substantial declines in tooth loss have been reported during the last several decades (7), historical rates for missing teeth may not be appropriate for comparison if the data were collected during a different time period. The NHANES III Phase 1 study reported tooth retention between 1988–91 of a civilian noninstitutional population and may be useful for comparison with the current study because it includes rates specific to a white, non-Hispanic, dentate population (8). The NHANES population was not restricted by exclusion of any medical condition and therefore may include as many as 5 percent diabetic subjects. If diabetic subjects have significantly more tooth loss, the findings of this national survey might be slightly higher than a nondiabetic control. However, NHANES III tooth loss rates (adjusted to the diabetic subject's age distribution) indicate an expected mean number of missing teeth of 2.46 teeth per person and an expected edentulism rate of 2.74 percent. The prevalences of missing teeth and edentulism in our dentate diabetic population (2.51 missing teeth and 3.94% edentulism) are numerically greater, although not significantly different than this national survey. Although our findings indicate that the duration of Type 1 diabetes is associated with greater missing teeth, its impact is unremarkable in comparison with this national survey.

Type 1 diabetes, associated with severe medical complications similar to Type 2 diabetes, has an early onset and generally impacts a younger population. Tooth loss, frequently the result of slowly progressing periodontal disease and caries, is seen generally in older populations and may be reported more commonly as an oral health consequence of Type 2 diabetes. As illustrated in Figure 1, which compares our IDDM subjects to age-adjusted NHANES III findings, there is an apparent lower prevalence of tooth loss in the lower age categories (<29 years) and a slightly higher prevalence in the older subjects (>30 years). This possible trend may suggest that the more severe oral health consequences of Type 1 diabetes occur later in life. In support of this hypothesis is Bacic et al.'s examination of 222 dentate diabetic adults that found tooth loss to be greater for the Type 2 patients than the Type 1 patients who were examined (12). Alternatively, tooth loss in the younger subjects of our population may be less pronounced because the

**TABLE 4**
**Results of Logistic Regression Model for Partial Tooth Loss in Type 1 Diabetic Subjects ($n$=299)**

| Variable | Parameter Estimate | Standard Error | Odds Ratio | 95% CI |
|---|---|---|---|---|
| Extensive periodontal disease | 1.995 | 0.597 | 7.35 | 2.49, 27.28 |
| Duration of diabetes longer than 24 years | 1.672 | 0.306 | 5.32 | 2.96, 9.84 |
| Not using dental floss | 0.871 | 0.323 | 2.39 | 1.27, 4.55 |
| Diabetic neuropathy | 0.832 | 0.355 | 2.29 | 1.15, 4.67 |
| Household income <$20,000 | 0.796 | 0.353 | 2.21 | 1.12, 4.47 |
| Multiple coronal decay/ fillings | 0.684 | 0.300 | 1.98 | 1.10, 3.58 |
| Bleeding on probing | 0.598 | 0.289 | 1.82 | 1.03, 3.23 |

medical management of IDDM, including improved strategies for glycemic control and smoking prevention, may have improved significantly in the last 20 years.

The overall prevalences reported for tooth loss and edentulism in this Type 1 diabetic study done in 1992–94 are slightly higher than reported by the 1985–86 NIDR adult survey of oral health in employed adults (26). In addition to the early time period of the study, the tooth loss reported by the NIDR adult study may not be comparable to our study population because Type 1 diabetes affects few minorities (less than 2% in the current study). Additionally, the diabetic population, unlike the NIDR employed adult study population, had an employment rate of only 69.5 percent. When only full-time employed dentate diabetic subjects ($n$=276) were analyzed, mean tooth loss decreased to 1.90 teeth per person and the edentulous rate decreased to 2.13 percent, values comparable to the NIDR survey. The impact of employment, and subsequent higher household income, on tooth loss and edentulism is substantial. Given that chronic medical diseases such as diabetes may be associated with life-style changes, caution should be taken when assessing the impact of the pathophysiology of a chronic disease such as diabetes on oral health when socioeconomic status is unknown.

Our oral health assessment found tooth loss to be related to the duration of Type 1 diabetes. The lack of an association between tooth loss and diabetes that has been reported by other investigators may be due to smaller study populations, younger ages, and level of glycemic control (14,19,21). The level of glycemic control (%A1), measured at only one time in the present study, may not be as reliable as evaluating repeated glycosylated hemoglobin measures over a period of years. In this study, the severity of diabetes, as measured by the prevalence of medical complications such as neuropathy, may better represent the long-term role of glycemic control on the oral health.

Glycemic control and medical complications of diabetes such as retinopathy have been previously associated with periodontal disease and tooth loss (12,16). Elevated blood glucose and glycosylated hemoglobin values, with subsequent medical complications, may be suggestive of common etiologic factors for the pathophysiology of dental diseases or may be viewed as possible surrogates for poor health behaviors. The lack of an association between tooth loss and glycosylated hemoglobin may indicate the primary importance of behavioral, cultural, and socioeconomic factors in determining loss of teeth and edentulism.

The high rate of retinal, neural, renal, and vascular diabetic complications in the edentulous subjects prompted the investigators to re-interview the edentulous patients to determine if there may have been any recommendations from the primary physician to extract infected teeth to remove possible sources of infection. Fourteen edentulous diabetic subjects responded to this poststudy telephone interview. Inquiries included date of extractions, reasons for not retaining their natural teeth, and parents' history of wearing dentures. The diabetic subjects reported having full dentures for an average of 20.9 years. Three patients reported that they had been referred to their dentist by their physician, although none stated that their diabetes was the specific reason for removal of their teeth. Of the 14 interviewed diabetic subjects, 13 had at least one parent who had worn complete dentures, and seven reported that both parents had worn complete dentures. The reason stated for extractions were primarily caries ("soft teeth") and periodontal disease ("bad gums").

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