Health insurance status is associated with periodontal disease progression among Gullah African-Americans with type 2 diabetes mellitus

Nicole M. Marlow, MSPH[1]; Elizabeth H. Slate, PhD[1]; Dipankar Bandyopadhyay, PhD[1]; Jyotika K. Fernandes, MD[2]; Renata S. Leite; DDS, MS[3]

1 Division of Biostatistics and Epidemiology, College of Medicine, Medical University of South Carolina, Charleston, SC
2 Division of Endocrinology, Diabetes, and Medical Genetics, College of Medicine, Medical University of South Carolina, Charleston, SC
3 Division of Periodontics, College of Dental Medicine, Medical University of South Carolina, Charleston, SC

Keywords
negative binomial regression; periodontal disease; periodontal disease progression; diabetes; Gullah African-Americans; access to healthcare; health insurance; glycemic-control; income.

Correspondence
Dr. Renata S. Leite, Division of Periodontics, College of Dental Medicine, Medical University of South Carolina, 30 Bee St, Room 115, Charleston, SC 29425. Tel.: 843-792-3908; Fax: 843-792-7809; e-mail: leiter@musc.edu. Nicole M. Marlow, Elizabeth H. Slate, and Dipankar Bandyopadhyay are with the Division of Biostatistics and Epidemiology, College of Medicine, Medical University of South Carolina, Charleston, SC. Jyotika K. Fernandes is with the Division of Endocrinology, Diabetes, and Medical Genetics, College of Medicine, Medical University of South Carolina, Charleston, SC. Renata S. Leite is with the Division of Periodontics, College of Dental Medicine, Medical University of South Carolina, Charleston, SC.

Received: 3/24/2010; accepted: 12/24/2010.

doi: 10.1111/j.1752-7325.2011.00243.x

Abstract

Objectives: Assess periodontal disease progression among Gullah African Americans with type 2 diabetes mellitus (T2DM) according to health insurance coverage.
Methods: From an ongoing clinical trial among T2DM Gullah, we extracted a cohort that was previously enrolled in a cross-sectional study ($N = 93$). Comparing prior exam to trial initiation, total tooth sites/person with periodontal disease progression events [evaluated separately: 2+ mm of clinical attachment loss (CAL), 2+ mm increased periodontal probing depths (PPD), bleeding on probing (BOP) emergence] were evaluated according to health insurance coverage using regression techniques appropriate for data with different counts of potential events per subject (varying tooth sites available). We used negative binomial regression techniques to account for overdispersion and fit multivariable models that also included baseline glycemic control (poor: glycated hemoglobin ≥7 percent, well: glycated hemoglobin <7 percent), history of established periodontitis, age, gender, body mass index, annual income, and oral hygiene behaviors. Final models included health insurance status, other significant predictors, and any observed confounders.
Results: Privately insured were most prevalent (41.94 percent), followed by uninsured (23.66 percent), Medicare (19.35 percent), and Medicaid (15.05 percent). Those with poor glycemic control (65.59 percent) were more prevalent than well-controlled (34.41 percent). CAL events ranged from 0 to 58.8 percent tooth sites/person (11.83 ± 12.44 percent), while PPD events ranged from 0 to 44.2 percent (8.66 ± 10.97 percent) and BOP events ranged from 0 to 95.8 percent (23.65 ± 17.21 percent). Rates of CAL events were increased among those who were uninsured [rate ratio (RR) = 1.75, $P = 0.02$], Medicare-insured (RR = 1.90, $P = 0.03$), and Medicaid-insured (RR = 1.89, $P = 0.06$).
Conclusions: Increased access to health care, including dental services, may achieve reduction in chronic periodontal disease progression (as determined by CAL) for this study population. These results are very timely given the March 2010 passing of the US healthcare reform bills.

Introduction

Chronic periodontal disease results in progressive destruction of the supporting tissues of the teeth as well as pocket formation, recession, or both. Periodontal disease has also been recognized as the sixth most common diabetes-related complication (1). There is evidence that periodontal disease can worsen glycemic control; also, (vice versa) proper management of periodontal disease can improve glycemic control (2).

Gullah African-Americans (or simply the Gullah) of coastal South Carolina and Georgia have a particularly high

degree of genetic risk for type 2 diabetes mellitus (T2DM), with a 3.3 familial relative risk, a figure which exceeds that seen in other communities (3). A previous report found significantly higher ($P < 0.001$) periodontal disease prevalence rates among Gullah with T2DM (70.6 percent) compared to national figures (National Health and Nutrition Survey III) for African-Americans with diabetes (31.3 percent) (4). The Gullah are direct descendants of rice plantation-enslaved Africans from Sierra Leone and other parts of West Africa who remained in their communities when slave practices became illegal (5). The Gullah today have considerably low non-African genetic admixtures as compared to other African-American populations (3.5 +/– 0.9 percent) (6), considered to be largely due to their longtime geographical, social, and cultural isolation. They are, predominantly, an underserved population, characterized by low socioeconomic conditions and live in very remote locations. This combination negatively impacts their access to health care (including dental services) and further complicates their ability to achieve and sustain wellness.

In an evaluation of dentate adults in the United States, Macek and Tomar (7) found that dental care visits in the preceding year were significantly less likely for those with no dental insurance [odds ratio (OR) = 0.55, 95 percent confidence interval (CI) = 0.47-0.63, adjusted for age, sex, race/ethnicity, education, poverty, diabetes, and periodontitis]. The Surgeon General's report *Oral Health in America* (8) describes that for every adult ≥18 years without medical insurance, there are three without dental insurance and, thus, lists medical insurance as a strong predictor of access to dental care. Wilper *et al.* (9) estimated that 16.6 percent of 18- to 64-year-olds with diabetes were uninsured. Several reports have shown that uninsured adults experience worse health outcomes than insured (10), and these negative effects may be more pronounced among individuals with chronic diseases (11).

The established link between periodontitis and diabetes calls for an increased need to study ways to control both diseases, particularly among populations with tremendous disparities for these conditions and, furthermore, generally low access to healthcare. Therefore, the aim of this report was to assess periodontal disease progression among Gullah African-Americans with T2DM according to health insurance status while adjusting for glycemic control, history of periodontitis, annual household income, and other factors.

Methods

Study population

We extracted data from an ongoing clinical trial of periodontal disease treatment interventions among adult Gullah African-Americans with T2DM. The clinical trial protocol was clearly explained to potential subjects and Institutional Review Board (IRB) approved consent and HIPAA forms were required for study inclusion. We selected subjects enrolled from December 2007 through March 2009 who were previously in a cross-sectional study limited to epidemiologic data collection (4). This process yielded a longitudinal cohort ($N = 98$), with evaluations at baseline (the previous epidemiologic study) and follow-up (the clinical trial enrollment examination, prior to treatment interventions). This cohort was further limited to subjects with non-missing data for health insurance status and glycated hemoglobin (HbA_{1c}) at baseline ($N = 93$). Follow-up time for this sample ranged from 1.93 to 4.08 years [mean = 3.01, standard deviation (SD) = 0.38]. The results of the clinical trial (after treatment interventions) will be presented in a future report.

Clinical trial subject inclusion criteria as well as clinical and demographic assessments have been described elsewhere (12). Two calibrated oral examiners (13) performed radiographic and soft-tissue exams and evaluated six sites per tooth (excluding third molars) for bacterial plaque presence, periodontal probing depths (PPD), attachment levels (AL), and bleeding on probing (BOP). Oral health behaviors, such as frequency of brushing, flossing, and visits to a dentist, were assessed through a questionnaire administered individually by study personnel.

Data analyses

All statistical analyses were performed using SAS software, version 9.2 for XP-Pro, Cary, NC, USA. Analyses for our final cohort ($N = 93$) were limited to tooth sites per person with non-missing data for periodontal measures (AL, PPD, and BOP) at both baseline and follow-up. Less than 3 percent of tooth sites from baseline were not measured at follow-up, a sufficiently small fraction so as to not appreciably affect the results reported herein. There were 10 231, 10 230, and 10 183 tooth sites with PPD, AL, and BOP measures, respectively, available at both baseline and follow-up (ranging from 24 to 168 tooth sites per person), and these were further included in our evaluations.

We measured "events" of periodontal disease progression, which were defined as tooth site changes from baseline to follow-up resulting in 2+ mm of clinical attachment loss (CAL), 2+ mm increases in PPD, and emergence of BOP, evaluated separately. Thresholds for tooth site-level disease advancement events were selected at levels that were deemed clinically meaningful and would considerably minimize the chances of incorrect classifications due to measurement error (13). After determining whether or not each tooth site had exceeded this threshold, results for each separate measure (CAL, PPD, and BOP) were summarized to total events of tooth site-level disease progression per person. Health insurance status was measured at baseline and categorized

Table 1 Characteristics of a Longitudinal Study Population of African-American Gullah with Type 2 Diabetes Mellitus, Overall and by Health Insurance Status

Variable	All (*N* = 93) Mean ± SD or *N* (%)	Private* (*N* = 39) Mean ± SD or *N* (%)	Medicare† (*N* = 18) Mean ± SD or *N* (%)	Medicaid‡ (*N* = 14) Mean ± SD or *N* (%)	Uninsured (*N* = 22) Mean ± SD or *N* (%)
Proportion of sites/person with CAL¶ events§	11.83% ± 12.44%	7.50% ± 6.88%	16.81% ± 14.88%	13.99% ± 12.39%	14.07% ± 15.93%
Proportion of sites/person with PPD• events∞	8.66% ± 10.97%	6.66% ± 8.42%	10.16% ± 13.18%	8.55% ± 9.63%	11.44% ± 11.54%
Proportion of sites/person with BOP# events**	23.65% ± 17.21%	25.03% ± 15.34%	25.88% ± 21.11%	16.43% ± 14.61%	23.96% ± 18.34%
Age at baseline (years)	55.14 ± 9.00	53.08 ± 9.05	60.28 ± 10.43	56.07 ± 7.72	54.00 ± 7.01
Poor glycemic control at baseline (HbA_{1c} ≥7%)	61 (65.59%)	27 (69.23%)	10 (55.56%)	10 (71.43%)	14 (63.64%)
Good glycemic control at baseline (HbA_{1c} <7%)	32 (34.41%)	12 (30.77%)	8 (44.44%)	4 (28.57%)	8 (36.36%)
Presence of established periodontitis at baseline	23 (24.73%)	6 (15.38%)	6 (33.33%)	3 (21.43%)	8 (36.36%)
No established periodontitis at baseline	70 (75.27%)	33 (84.62%)	12 (66.67%)	11 (78.57%)	14 (63.64%)
Gender: female	73 (78.49%)	30 (76.92%)	15 (83.33%)	10 (71.43%)	18 (81.82%)
Gender: male	20 (21.51%)	9 (23.08%)	3 (16.67%)	4 (28.57%)	4 (18.18%)
Smoking status: current	8 (8.60%)	2 (9.09%)	1 (5.56%)	3 (21.43%)	2 (9.09%)
Smoking status: past	14 (15.05%)	5 (12.82%)	3 (16.67%)	2 (14.29%)	4 (18.18%)
Smoking status: never	71 (76.34%)	32 (82.05%)	14 (77.78%)	9 (69.29%)	16 (72.73%)
Body mass index (kg/m^2): obese (>30)	66 (70.97%)	27 (69.23%)	14 (77.78%)	12 (85.71%)	13 (59.09%)
Body mass index (kg/m^2): overweight (25-30)	18 (19.35%)	8 (20.51%)	3 (16.67%)	1 (7.14%)	6 (27.27%)
Body mass index (kg/m^2): normal (<25)	5 (5.38%)	3 (7.69%)	0 (0%)	0 (0%)	2 (9.09%)
Body mass index (kg/m^2): data missing	4 (4.30%)	1 (2.56%)	1 (5.56%)	1 (7.14%)	1 (4.55%)
Annual household income: <$5,000	9 (9.68%)	0 (0%)	1 (5.56%)	3 (21.43%)	3 (21.43%)
Annual household income: $5,000-9,999	18 (19.35%)	3 (7.69%)	4 (22.22%)	5 (35.71%)	6 (27.27%)
Annual household income: $10,000-14,999	18 (19.35%)	2 (5.13%)	4 (22.22%)	5 (35.71%)	7 (31.82%)
Annual household income: $15,000-24,999	20 (21.51%)	13 (33.33%)	4 (22.22%)	0 (0%)	3 (13.64%)
Annual household income: ≥ $25,000	27 (29.03%)	20 (51.28%)	5 (27.78%)	1 (7.14%)	1 (4.55%)
Annual household income: data missing	1 (1.08%)	1 (2.56%)	0 (0%)	0 (0%)	0 (0%)
Frequency of toothbrushing: ≤ 1 time/day	28 (30.11%)	13 (33.33%)	4 (22.22%)	5 (35.71%)	6 (27.27%)
Frequency of toothbrushing: ≥ 2 times/day	65 (69.89%)	26 (66.67%)	14 (77.78%)	9 (64.29%)	16 (72.73%)
Flossing: no	19 (20.43%)	3 (7.69%)	8 (44.44%)	6 (42.86%)	2 (9.09%)
Flossing: yes	74 (79.57%)	36 (92.31%)	10 (55.56%)	8 (57.14%)	20 (90.91%)
Dental visits: never/only for problems	55 (59.14%)	17 (43.59%)	11 (61.11%)	10 (71.43%)	17 (77.27%)
Dental visits: ≥1 time/year	38 (40.86%)	22 (56.41%)	7 (38.89%)	4 (28.57%)	5 (22.73%)

* Private insurance, without Medicare or Medicaid coverage.
† Medicare without Medicaid coverage.
‡ Any Medicaid coverage.
¶ Clinical attachment loss.
§ CAL ≥2 mm.
• Periodontal probing depths.
∞ PPD increased by ≥2 mm.
Bleeding on probing.
** Emergence of BOP.

according to "private" (private health plan and/or the South Carolina state employees dental plan, without Medicaid or Medicare), "Medicaid" (any Medicaid enrollment), "Medicare" (enrollment in Medicare without Medicaid, with or without a private health plan supplement and/or the SC state employee dental plan), and "uninsured" (no health or dental plan reported). Other covariates (also measured at baseline) included glycemic control [poor: $HbA_{1c} \geq 7$ percent, well: $HbA_{1c} < 7$ percent (14)], presence of established periodontitis (EP) according to the definition by Machtei *et al*. (15) (yes/no), age (years), gender (male/female), smoking status (never/current/past), body mass index (BMI) (BMI <25 = normal/25-30 = overweight/> 30 = obese/data missing), annual income (<$5,000/year; $5,000-9,999/year; $10,000-14,999/year; $15,000-24,999/year; ≥$25,000/year; data missing), toothbrushing (≤1 time/day; ≥2 times/day), flossing (yes/no), and dental visits (≥1 time/year; never/only for problems).

Periodontal disease progression (CAL, PPD, and BOP events per person), health insurance status, glycemic control, and all other covariates were first summarized by mean and SD results (if continuous) or frequency results (if categorical), and results were reported by their overall and health insurance status-specific distributions (Table 1). We further used regression techniques appropriate for count data with different numbers of potential events (e.g., varying tooth sites available per subject) to compare rates of CAL, PPD, and BOP events per person by health insurance status. After fitting univariable Poisson regression models by health insurance, we determined that it was necessary to account for

overdispersion. If the ratio of the Poisson regression model deviance to its degrees of freedom (d.f.) is much larger than 1, then variability beyond that consistent with the Poisson distribution is implied (16). For our fitted univariable Poisson regression models by health insurance, the deviance/d.f. ratios included 10.11 for CAL events, 10.44 for PPD events, and 11.20 for BOP events. In the case of overdispersion, negative binomial (NB) regression methods can be used to allow greater flexibility in modeling the relationship between the mean and variance of Y_i (16). For the NB distribution, Var $(Y_i) = \mu + k\,\mu^2$, where k is an additional model parameter. We fit NB models using PROC GENMOD in SAS, which reports k as the "dispersion" parameter; this resulted in adequate correction for overdispersion (deviance/d.f. for univariable NB models by health insurance: CAL events = 1.20, PPD events = 1.18, BOP events = 1.18) (16).

Three separate series of multivariable NB models were produced according to each measure (CAL, PPD, and BOP events per person). Predictors other than insurance status and any determined confounders were successively removed through a process of backward elimination based on P values of the estimated regression coefficients (removing those with $P > 0.05$). The final three models included insurance status, determined confounders, and all other predictors that showed significant associations with the respective progression measure. The estimated regression coefficients from these final models were used to calculate covariate-adjusted rate ratios (RR) and associated 95 percent CI for progression events (CAL, PPD, and BOP) per person (16).

Results

Table 1 provides descriptive statistics for the study population as a whole and by health insurance status. Privately insured were most prevalent (41.94 percent), followed by uninsured (23.66 percent), Medicare-insured (19.35 percent), and Medicaid-insured (15.05 percent). Poorly controlled diabetes at baseline (65.59 percent) was more prevalent than well-controlled (34.41 percent). Most had no EP at the baseline examination (75.27 percent), yet these results varied greatly according to health insurance status, with 84.62 percent among privately insured, 78.57 percent among Medicaid-insured, 66.67 percent among Medicare-insured, and 63.64 percent among uninsured. The proportion of tooth sites/person with CAL events ranged from 0 to 58.82 percent (11.83 percent $\pm$ 12.44 percent), while similar proportions of PPD events ranged from 0 to 44.23 percent (8.66 percent $\pm$ 10.97 percent) and BOP events ranged from 0 to 95.83 percent (23.65 percent $\pm$ 17.21 percent). Results for CAL and PPD events also varied greatly according to health insurance status, with respective means of 14.07 percent and 11.44 percent among uninsured compared to 7.50 percent and 6.66 percent among privately insured.

Patient age ranged from 34 to 77 years (55.14 $\pm$ 9.00). Few were within normal range for BMI (5.38 percent), followed by those who were overweight (19.35 percent) and those who were obese (70.97 percent). Females (78.49 percent) were more prevalent that males (21.51 percent), consistent with previously reported gender-related participation rate differences for studies involving the Gullah population (17). Most reported no history of smoking (76.34 percent), followed by past (15.05 percent) and current (8.6 percent) smokers. Annual household incomes were generally low, with 9.68 percent reporting <$5 000; 19.35 percent reporting $5,000-9 999; 19.35 percent reporting $10,000-14 999; 21.51 percent reporting $15,000-24 999; and 29.03 percent reporting $\geq$$25,000. The majority reported good daily oral hygiene habits, including flossing (79.57 percent) and toothbrushing $\geq$2 times/day (69.89 percent); yet, less than half reported visiting a dentist at least once annually (40.86 percent).

The final CAL model showed that rates of CAL events per person were significantly associated with health insurance status (Table 2). Relative to privately insured groups, rates of CAL events were significantly higher for uninsured (RR = 1.75, 95 percent CI = 1.04-2.94) and for Medicare-insured (RR = 1.90, 95 percent CI = 1.09-3.30). Yet, marginally increased rates of CAL events were observed among Medicaid-insured compared to privately insured (RR = 1.89, 95 percent CI = 0.98-3.63, $P = 0.06$) (Table 2). Additionally, subjects with history of EP (RR = 1.92, 95 percent CI = 1.31-2.83) and those who were older (RR = 1.04, 95 percent CI = 1.02-1.06), obese (RR = 4.12, 95 percent CI = 1.81-9.41), overweight (RR = 2.88, 95 percent CI = 1.17-7.08), and "past" smokers (RR = 1.83, 95 percent CI = 1.17-2.88) had significantly increased rates of CAL events (Table 2).

The final PPD model showed that rates of PPD events per person were not significantly associated with health insurance status (Table 3). Rates of PPD events were significantly lower for females (RR = 0.45, 95 percent CI = 0.26-0.80). Yet, rates were significantly higher for subjects with history of EP (RR = 2.26, 95 percent CI = 1.39-3.68) and those who were older (RR = 1.03, 95 percent CI = 1.004-1.06) and obese (RR = 2.76, 95 percent CI = 1.02-7.43) (Table 3).

The final BOP model showed that rates of BOP events per person were not significantly associated with health insurance status (Table 4). However, rates of BOP events were significantly lower for those with no history of EP (RR = 0.69, 95 percent CI = 0.49-0.97) (Table 4).

Discussion

Despite the links between periodontal disease and diabetes, recent reports have shown that dentate adults with diabetes are less likely to seek dental care than those without diabetes (7,18). Some have hypothesized that periodontitis acts as a deterrent to dental care due to the potential discomforts and

Table 2 Results from Multivariable Negative Binomial Regression Models for the Relationship Between Health Insurance Status and Counts of Tooth Sites with Clinical Attachment Loss (CAL) Events (CAL ≥2 mm) among a Longitudinal Study Population of Gullah African-Americans with Diabetes (*N* = 93)

	Full model results (Deviance/d.f. = 1.46) (AIC = 634.38)			Final model results (Deviance/d.f. = 1.40) (AIC = 628.42)					
								RR 95% CI	
Variable	β	SE	*P*	β	SE	*P*	RR	LL	UL
Intercept	–5.93	0.77	<0.01	–5.88	0.71	<0.01	–	–	–
Uninsured	0.63	0.29	0.03*	0.64	0.28	0.02*	1.75	1.04	2.94
Any Medicaid coverage (Medicaid)	0.63	0.34	0.06	0.63	0.33	0.06	1.89	0.98	3.63
Medicare without Medicaid coverage (Medicare)	0.56	0.27	0.04*	0.56	0.26	0.03*	1.90	1.09	3.30
Poor glycemic control at baseline (HbA_{1c} ≥7%)	0.00	0.18	0.98	–	–	–	–	–	–
Presence of established periodontitis at baseline	0.65	0.20	<0.01*	0.65	0.20	<0.01*	1.92	1.31	2.83
Age at baseline (years)	0.04	0.01	<0.01*	0.04	0.01	<0.01*	1.04	1.02	1.06
Gender: female	–0.49	0.23	0.03*	–0.50	0.21	0.02*	0.61	0.40	0.92
Body mass index (kg/m^2): obese (>30)	1.42	0.44	<0.01*	1.42	0.42	<0.01*	4.12	1.81	9.41
Body mass index (kg/m^2): overweight (25-30)	1.07	0.46	0.02*	1.06	0.46	0.02*	2.88	1.17	7.08
Body mass index (kg/m^2): data missing	–0.90	0.75	0.23	–0.92	0.74	0.21	0.40	0.09	1.70
Smoking status: current	–0.01	0.36	0.97	–0.02	0.35	0.95	0.98	0.50	1.93
Smoking status: past	0.61	0.23	0.01*	0.61	0.23	0.01*	1.83	1.17	2.88
Annual household income: <$5,000	–0.30	0.41	0.46	–0.28	0.40	0.48	0.75	0.34	1.64
Annual household income: $5,000-9,999	–0.25	0.31	0.41	–0.25	0.31	0.42	0.78	0.42	1.43
Annual household income: $10,000-14,999	–0.25	0.32	0.43	–0.25	0.31	0.42	0.78	0.43	1.43
Annual household income: $15,000-24,999	–0.36	0.26	0.17	–0.36	0.25	0.14	0.70	0.43	1.13
Annual household income: data missing	–0.84	0.93	0.37	–0.85	0.92	0.36	0.43	0.07	2.59
Frequency of toothbrushing: ≤1 time/day	–0.01	0.21	0.98	–	–	–	–	–	–
Flossing: no	–0.30	0.26	0.25	–0.28	0.23	0.23	0.75	0.48	1.19
Dental visits: never/only for problems	0.04	0.20	0.85	–	–	–	–	–	–
Dispersion parameter	0.44	0.08	–	0.44	0.08	–	–	–	–

* $P \leq 0.05$.

CI, confidence interval; LL, lower limit; RR, rate ratio; SE, standard error; UL, upper limit.

expenses related to periodontal therapy. Macek and Tomar (7) found that diabetes and periodontitis status were independent predictors of dental care visits in the preceding year among dentate adults, with each diseased group showing negative associations; however, there was no significant interaction between these two variables, meaning the associations between diabetes and dental care visits were consistent for both those with and without periodontitis. The authors suggested that dental care patterns among dentate adults with diabetes are associated with indirect factors, such as lack of knowledge concerning the relationship between oral health and diabetes management, negative attitudes concerning the healthcare system, and the various competing healthcare costs related to diabetes (7).

Healthcare costs can be considerable hindrances for patients with diabetes and inadequate or no health insurance coverage. As such, these individuals may not be able to maintain the health-enhancing behaviors, including dental care, needed to most effectively manage their disease and prevent or treat diabetes-related complications, such as periodontal disease. Wilper *et al*. (9) found that uninsured patients with diabetes were significantly more likely than insured to report no standard site for care when they were sick (9.3 percent versus 1.8 percent, respectively, $P < 0.01$, controlling for sex, race/ethnicity, and age) as well as no visits to a health professional in the past 12 months (11.6 percent versus 2.0 percent, respectively, $P = 0.03$, controlling for sex, race/ethnicity, and age). Medical insurance coverage is also strongly related to access to dental care (8), and Wamala *et al*. (19) suggested that better access to dental care could eliminate or significantly decrease socioeconomic-related oral health disparities.

A previous longitudinal study of patients who received high-cost dental care within the Swedish National Dental Insurance System showed low progression of severe periodontal disease during a 20-year follow-up, indicating that receipt of dental care decreased patient level of dental disease (20). The US Medicare system does not cover routine dental care or most dental procedures (e.g., cleanings, fillings, tooth extractions, dentures). Furthermore, South Carolina Medicaid (21) only pays for emergency dental services among recipients ages ≥21 years. Hanson and Persson (22) assessed the use of dental services and behavioral beliefs in relation to dental diseases of a Medicaid-eligible adult population in Kitsap County, WA, and concluded that the primary barriers

Table 3 Results from Multivariable Negative Binomial Regression Models for the Relationship between Health Insurance Status and Counts of Tooth Sites with Probing Pocket Depth (PPD) Events (PPD Increases ≥2 mm) among a Longitudinal Study Population of Gullah African-Americans with Diabetes (*N* = 93)

	Full model results (Deviance/d.f. = 1.43) (AIC = 605.33)			Final model results (Deviance/d.f. = 1.34) (AIC = 597.67)					
								RR 95% CI	
Variable	β	SE	*P*	β	SE	*P*	RR	LL	UL
Intercept	–5.23	0.95	<0.01	–4.88	0.87	<0.01	–	–	–
Uninsured	0.47	0.35	0.18	0.50	0.35	0.15	1.65	0.83	3.27
Any Medicaid coverage (Medicaid)	0.21	0.44	0.63	0.21	0.42	0.61	1.24	0.54	2.85
Medicare without Medicaid coverage (Medicare)	0.04	0.35	0.91	0.05	0.33	0.89	1.05	0.55	2.00
Poor glycemic control at baseline (HbA_{1c} ≥7%)	–0.07	0.23	0.77	–	–	–	–	–	–
Presence of established periodontitis at baseline	0.77	0.25	<0.01*	0.82	0.25	<0.01*	2.26	1.39	3.68
Age at baseline (years)	0.04	0.01	0.01*	0.03	0.01	0.02*	1.03	1.00	1.06
Gender: female	–0.69	0.32	0.03*	–0.79	0.29	0.01*	0.45	0.26	0.80
Body mass index (kg/m^2): obese (>30)	1.00	0.53	0.06	1.01	0.51	0.05*	2.76	1.02	7.43
Body mass index (kg/m^2): overweight (25-30)	0.41	0.56	0.47	0.44	0.54	0.42	1.55	0.54	4.49
Body mass index (kg/m^2): data missing	–1.31	0.91	0.15	–1.45	0.84	0.08	0.24	0.05	1.21
Smoking status: current	0.01	0.50	0.98	–	–	–	–	–	–
Smoking status: past	0.38	0.30	0.20	–	–	–	–	–	–
Annual household income: <$5,000	0.01	0.52	0.98	0.18	0.51	0.72	1.20	0.45	3.23
Annual household income: $5,000-9,999	–0.08	0.39	0.84	–0.08	0.39	0.85	0.93	0.43	2.01
Annual household income: $10,000-14,999	–0.20	0.41	0.63	–0.10	0.40	0.81	0.91	0.42	1.98
Annual household income: $15,000-24,999	–0.02	0.35	0.95	0.08	0.32	0.81	1.08	0.58	2.00
Annual household income: data missing	0.22	1.05	0.83	0.19	1.04	0.85	1.21	0.16	9.21
Frequency of toothbrushing: ≤1 time/day	0.07	0.29	0.81	–	–	–	–	–	–
Flossing: no	–0.22	0.36	0.54	–0.12	0.31	0.70	0.89	0.48	1.63
Dental visits: never/only for problems	0.17	0.27	0.53	–	–	–	–	–	–
Dispersion parameter	0.74	0.13	–	0.76	0.13	–	–	–	–

* $P \leq 0.05$.

CI, confidence interval; LL, lower limit; RR, rate ratio; SE, standard error; UL, upper limit.

to the utilization of dental services in their low-income Medicaid population included: a) a preoccupation with other daily issues, financial being the greatest; b) an attitude of waiting for a problem to occur before seeking dental care; and c) tooth extraction as the solution or only available treatment option. Our results reported herein showed disparities in chronic periodontal disease progression among those without private health insurance. We observed significantly ($P < 0.05$) increased rates of CAL events among the uninsured (RR = 1.75) and Medicare-insured (RR = 1.90), and marginally ($P = 0.06$) increased rates of CAL events among the Medicaid-insured (RR = 1.89).

Smokers have six to seven times more alveolar bone loss than nonsmokers in studies in the United States and other countries (18,23,24). Final models showed that "past" smokers had significantly increased rates of CAL events (RR = 1.83), while no significance was found among "current" smokers for CAL events, perhaps due to the small sample in this group or from the limited longitudinal aspect of the study. Poor oral health care has traditionally been linked to lower socioeconomic status (25,26), which is consistent with our results for those without private health insurance. In addition, our final models for CAL and PPD events included annual household income as a confounder for the health insurance status associations. Results also showed significantly increased rates of CAL (RR = 4.12) and PPD events (RR = 2.76) among those who were obese, and significantly increased CAL events (RR = 2.88) among those who were overweight. These results are consistent with reports from Wood *et al.* (27) and Khader *et al.* (28) reporting that CAL and PPD, as indicators of periodontal disease, were correlated with increased BMI. Studies have also shown that periodontal disease prevalence and severity increases with age, as do other systemic disease conditions such as diabetes, heart disease, and obesity. It is apparent that aging is associated with changes that lead to a progressive, irreversible deterioration of tissues and organs (29), and we observed that rates of CAL events significantly increased by 4 percent with every year increase in age.

The results of this report may be limited in their generalizability as they may only apply to this specific population living in the Sea Islands of South Carolina. Our study population is also limited to subjects with T2DM, and those with well-controlled diabetes served as controls for the poorly

Table 4 Results from Multivariable Negative Binomial Regression Models for the Relationship between Health Insurance Status and Counts of Tooth Sites with Bleeding on Probing (BOP) Events (BOP emergence) among a Longitudinal Study Population of Gullah African-Americans with Diabetes (*N* = 93)

	Full model results (Deviance/d.f. = 1.44) (AIC = 790.33)			Final model results (Deviance/d.f. = 1.29) (AIC = 775.47)					
								RR 95% CI	
Variable	β	SE	*P*	β	SE	*P*	RR	LL	UL
Intercept	–1.50	0.70	0.03	–1.20	0.14	<0.01	–	–	–
Uninsured	0.10	0.25	0.70	0.12	0.24	0.61	1.13	0.70	1.81
Any Medicaid coverage (Medicaid)	–0.37	0.31	0.23	–0.39	0.29	0.18	0.67	0.38	1.19
Medicare without Medicaid coverage (Medicare)	0.10	0.24	0.67	0.09	0.21	0.66	1.10	0.72	1.66
Poor glycemic control at baseline (HbA_{1c} ≥7%)	0.06	0.16	0.71	–	–	–	–	–	–
Presence of established periodontitis at baseline	–0.34	0.18	0.05	–0.37	0.17	0.03*	0.69	0.49	0.97
Age at baseline (years)	0.00	0.01	0.79	–	–	–	–	–	–
Gender: female	0.30	0.21	0.14	–	–	–	–	–	–
Body mass index (kg/m^2): obese (>30)	–0.19	0.38	0.61	–	–	–	–	–	–
Body mass index (kg/m^2): overweight (25-30)	–0.19	0.40	0.64	–	–	–	–	–	–
Body mass index (kg/m^2): data missing	–0.37	0.56	0.52	–	–	–	–	–	–
Smoking status: current	0.46	0.31	0.14	0.30	0.27	0.28	1.35	0.79	2.31
Smoking status: past	0.10	0.23	0.67	0.04	0.21	0.84	1.04	0.69	1.58
Annual household income: <$5,000	–0.53	0.37	0.15	–0.39	0.33	0.25	0.68	0.35	1.31
Annual household income: $5,000-9,999	–0.43	0.26	0.10	–0.34	0.25	0.17	0.71	0.44	1.16
Annual household income: $10,000-14,999	–0.35	0.28	0.21	–0.23	0.26	0.38	0.80	0.48	1.32
Annual household income: $15,000-24,999	–0.42	0.23	0.07	–0.34	0.21	0.11	0.71	0.47	1.08
Annual household income: data missing	–1.10	0.76	0.15	–1.15	0.73	0.12	0.32	0.08	1.33
Frequency of toothbrushing: ≤1 time/day	0.10	0.19	0.60	–	–	–	–	–	–
Flossing: no	–0.05	0.24	0.84	–	–	–	–	–	–
Dental visits: never/only for problems	0.17	0.20	0.38	–	–	–	–	–	–
Dispersion parameter	0.42	0.07	–	0.43	0.07	–	–	–	–

* $P \leq 0.05$.

CI, confidence interval; LL, lower limit; RR, rate ratio; SE, standard error; UL, upper limit.

controlled. Additionally, our study design limits interpretations of temporal relationships among measures recorded at baseline, such as health insurance status, EP, diabetes, and BMI. A prospective cohort study, including a nondiseased population (i.e., no diabetes, normal BMI, and no EP) per each health insurance group, may address this problem. Our observed associations could also in part be due to common lifestyle characteristics that make individuals more prone to all three diseases. Still, our results showed that health insurance status was significantly associated with longitudinal progression of chronic periodontal disease. Likewise, we observed significant associations for BMI status with rates of CAL and PPD events independent of health insurance status.

Strengths of this report include an opportunity to study periodontal disease progression among subjects with T2DM and no recent antibiotic treatment, given that the eligibility criteria for the clinical trial (from which we extracted the follow-up visit for our cohort) included no antibiotics received within 6 months prior to enrollment. Furthermore, this study population is especially suitable for our objectives given the increased risks for T2DM among the Gullah and the profoundly high prevalence of periodontitis among the Gullah with T2DM. Analyses involving this distinct, homogenous population (e.g., substantially low non-African genetic admixture and significant preservation of their African cultural heritage) provide further support to the clinical relevance of Gullah-related study findings. The data analyzed for this report are also very comprehensive, from the subject level to the tooth site level, and this allowed adjustments for key potential confounders (including glycemic control, annual household income, smoking status, age, BMI, and oral hygiene behaviors).

In conclusion, the results reported herein suggest that increased access to healthcare, including dental services, may achieve a reduction in chronic periodontal disease progression (as determined by CAL) for this study population. These results are very timely given the March 2010 passing of the US healthcare reform bills. Research has shown profound relationships between oral health and overall systemic health, and the American Association for Dental Research has called for policy changes that will include prevention, diagnosis, and treatment of oral diseases.

Acknowledgments

This work was conducted with support from the National Institutes of Health, National Center of Research Resources Grant Number P20 RR017696, South Carolina COBRE in Oral Health. It was also supported in part by grants M01 RR001070 from the National Center for Research Resources, National Institutes of Health, and R03 DE020114 from the National Institute for Dental and Craniofacial Research, National Institutes of Health, as well as the MUSC Division of Biostatistics and Epidemiology.

References

1. Loe H. Periodontal disease. The sixth complication of diabetes mellitus. *Diabetes Care.* 1993;**16**(1):329-34.
2. Grossi SG. Treatment of periodontal disease and control of diabetes: an assessment of the evidence and need for future research. *Ann Periodontol.* 2001;**6**(1):138-45.
3. Garvey WT, McLean DC Jr., Spruill I. The search for obesity genes in isolated populations: Gullah speaking African Americans and the role of uncoupling protein 3 as a thrifty gene. In: Medeiros G, Halpern A, Bouchard C, editors. *Progress in obesity research*. Paris, France: Hohn Libbey Eurotext; 2003. p. 373-80.
4. Fernandes JK, Wiegand RE, Salinas CF, Grossi SG, Sanders JJ, Lopes-Virella MF, Slate E. Periodontal disease status in Gullah African Americans with type 2 diabetes living in South Carolina. *J Periodontol.* 2009;**80**(7):1062-8.
5. McLean DC Jr., Spruill I, Argyropoulos G, Page GP, Shriver MD, Garvey WT. Mitochondrial DNA (mtDNA) haplotypes reveal maternal population genetic affinities of Sea Island Gullah-speaking African Americans. *Am J Phys Anthropol.* 2005;**127**(4):427-38.
6. Parra EJ, Kittles RA, Argyropoulos G, Pfaff CL, Hiester K, Bonilla C, Sylvester N, Parrish-Gause D, Garvey WT, Jin L, McKeigue PM, Kamboh MI, Ferrell RE, Pollitzer WS, Shriver MD. Ancestral proportions and admixture dynamics in geographically defined African Americans living in South Carolina. *Am J Phys Anthropol.* 2001;**114**(1):18-29.
7. Macek MD, Tomar SL. Dental care visits among dentate adults with diabetes and periodontitis. *J Public Health Dent.* 2009;**69**(4):284-9.
8. U.S. Department of Health and Human Services. Oral Health in America. A Report of the Surgeon General. Rockville MD; 2000, p. 2-3.
9. Wilper AP, Woolhandler S, Lasser KE, McCormick D, Bor DH, Himmelstein DU. A national study of chronic disease prevalence and access to care in uninsured US adults. *Ann Intern Med.* 2008 August 5;**149**(3):170-6.
10. McWilliams JM. Health consequences of uninsurance among adults in the United States: recent evidence and implications. *Milbank Q.* 2009;**87**(2):443-94.
11. Institute of Medicine. *Care without coverage: too little. Too late*. Washington, DC: National Academy Press; 2002.
12. Bandyopadhyay D, Marlow NM, Fernandes JK, Leite RS. Periodontal disease progression and glycemic control among Gullah African Americans with type-2 dibetes. *J Clin Periodontol.* 2010;**37**(6):501-9.
13. Hill EG, Slate EH, Wiegand RE, Grossi SG, Salinas CF. Study design for calibration of clinical examiners measuring periodontal parameters. *J Periodontol.* 2006;**77**(7):1129-41.
14. American Diabetes Association. Standards of medical care in diabetes – 2006. *Diabetes Care.* 2006;**29**(Suppl 1):S4-42.
15. Machtei EE, Christersson LA, Grossi SG, Dunford R, Zambon JJ, Genco RJ. Clinical criteria for the definition of "established periodontitis". *J Periodontol.* 1992;**63**(3):206-14.
16. Hilbe JM. *Negative binomial regression: modeling. Negative binomial regression*. New York: Cambridge University Press; 2007.
17. Johnson-Spruill I, Hammond P, Davis B, McGee Z, Louden D. Health of Gullah families in South Carolina with type 2 diabetes: diabetes self-management analysis from project SuGar. *Diabetes Educ.* 2009;**35**(1):117-23.
18. Tomar SL, Lester A. Dental and other health care visits among US adults with diabetes. *Diabetes Care.* 2000;**23**(10):1505-10.
19. Wamala S, Merlo J, Bostrom G. Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National Surveys of Public Health 2004-2005. *J Epidemiol Community Health.* 2006;**60**(12):1027-33.
20. Petersson K, Pamenius M, Eliasson A, Narby B, Holender F, Palmqvist S, Håkansson J. 20-year follow-up of patients receiving high-cost dental care within the Swedish Dental Insurance System: 1977-1978 to 1998-2000. *Swed Dent J.* 2006;**30**(2):77-86.
21. South Carolina Department of Health and Human Services. What Services Are Covered? SC State Government Site. [cited 2010 March 2]. Available from: http://www.scdhhs.gov/InsideDHHS/Bureaus/EligiblityPolicyAndOversight/What Services Are Covered.ASP.
22. Hanson WL, Persson GR. Periodontal conditions and service utilization behaviors in a low income adult population. *Oral Health Prev Dent.* 2003;**1**(2):99-109.
23. Bergstrom J, Preber H. Tobacco use as a risk factor. *J Periodontol.* 1994;**65**(Suppl 5):545-50.
24. Grossi SG, Genco RJ, Machtei EE, Ho AW, Koch G, Dunford R, Zambon JJ, Hausmann E. Assessment of risk for periodontal disease. II. Risk indicators for alveolar bone loss. *J Periodontol.* 1995;**66**(1):23-9.
25. Vargas CM, Manski RJ. Dental expenditures and source of payment by race/ethnicity and other sociodemographic characteristics. *J Public Health Dent.* 1999;**59**(1):33-8.
26. Sabbah W, Tsakos G, Sheiham A, Watt RG. The role of health-related behaviors in the socioeconomic disparities in oral health. *Soc Sci Med.* 2009;**68**(2):298-303.

27. Wood N, Johnson RB, Streckfus CF. Comparison of body composition and periodontal disease using nutritional assessment techniques: Third National Health and Nutrition Examination Survey (NHANES III). *J Clin Periodontol.* 2003;**30**(4):321-7.
28. Khader YS, Bawadi HA, Haroun TF, Alomari M, Tayyem RF. The association between periodontal disease and obesity among adults in Jordan. *J Clin Periodontol.* 2009;**36**(1): 18-24.
29. Mackenzie IC, Holm-Pedersen P, Karring T. Age changes in the oral mucous membranes and periodontium. In: Holm-Pedersen P, Loe H, editors. *Geriatric dentistry*. 1st ed. Copenhagen: Munksgaard; 1977. p. 102-13.