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Predictive Power of the Severity Measure of Attachment Loss for Periodontal Care Need

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Abstract

Background: The prevalence of periodontal diseases is high, and >15% of adults have severe gum disease. Clinical attachment loss (AL) is one of the most important measures for periodontal disease severity. With AL, one could measure the worst scenario, the average, or the cumulative sum of AL among all teeth. The objective of this study is to evaluate which of the 15 measures of periodontal problems (e.g., maximum, mean, and cumulative AL) best predict the need for periodontal treatment.

Methods: Using detailed periodontal data obtained through clinical examination from the National Health and Nutrition Examination Survey 1999 to 2002, weighted logistic regression was used to model the periodontal treatment need of 15 different periodontal disease measures. The outcome measure is the clinically determined periodontal need.

Results: After adjustment for the covariates of age, sex, ethnicity, education, smoking status, and diabetes, the three most predictive measures were identified as: 1) the sum of the maximum mid-buccal (B) and mesio-buccal (MB) measures, which reflects the worst case of both B and MB measures; 2) the sum of the maximum MB measure or the worst case of the MB measure; and 3) the sum of all B and MB measures, or the cumulative AL measures.

Conclusions: Cumulative periodontal morbidity, particularly the worst case of B and MB measures, has the strongest impact on the need for periodontal care. All the demographic variables and covariates follow the classic pattern of association with periodontal disease.

Keywords

Logistic model; nutrition surveys; oral health; periodontal attachment loss; periodontal diseases

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Over the last decade, dentistry has developed methods to identify individuals at high risk for dental diseases, based on epidemiologic evidence that dental diseases are not randomly distributed but are more likely to affect certain teeth. Persson[1] proposed a model with both site-based and patient-based periodontal diagnostics and differential severity risk factors. Site-specific factors include: 1) clinical diagnostic measure and radiographs; 2) assays of gingival crevicular fluid for specific bacteria; and 3) specific markers of inflammation (i.e., enzymes, cytokines, and immune markers). Patient-based factors of periodontitis include: 1) clinical diagnostic measures; 2) serum assays for antibodies to specific pathogens; 3) genetic factors; 4) social and behavioral factors such as smoking; 5) oral hygiene habits; and 6) quality-of-life issues revolving around self-perception and psychologic tests. Associations were found among periodontal disease and systemic diseases, including cardiovascular disease, preterm gestation/low birth weight, diabetes, and osteoporosis.[2] The clinical measures common to both site-based and patient-based risk factors are probing depth (PD), bone loss, and clinical attachment loss (AL). PD is used to diagnose the presence of disease and assess the results of treatment interventions. AL is considered the gold standard. However, all these measures represent the cumulative lifetime periodontal experience of the individual. They do not provide an assessment of current disease activity.[3] Only PD >4 mm with bleeding on probing (BOP)[4] is indicative of active inflammatory periodontal disease. Indices have been developed to examine various attributes of periodontal disease such as plaque, gingivitis, calculus, and BOP.[5,6] Russell[7] considered color change for gingivitis and the distortion of the gingival margin caused by calculus when developing a composite score in the Periodontal Index. Ramfjord[8] also took calculus and gingivitis into consideration when developing the Periodontal Disease Index. The Community Periodontal Index of Treatment Needs[9] was developed to estimate treatment needs in populations. Dividing the mouth into sextants, it considers gingival bleeding, calculus, and deep and shallow periodontal pockets. The score is the accumulation of the worst score in each sextant.

The standard clinical method for measuring periodontal disease is a full-mouth examination at six sites per tooth. In large epidemiologic surveys of periodontal disease, time limitations for examiner and patient make the labor-intensive nature of a standard examination out of the question. This has led investigators to develop partial recording protocols (PRPs),[10] which include a fixed set of teeth with a subset of intra-oral sites per tooth. Ramfjord[8] examined the mesio-buccal (MB) site on six specific teeth. Ainamo and Ainamo[11] selected quadrants, and Beck et al.[12] suggested a simple random sample of sites per person. The surveys included in the National Health and Nutrition Examination Survey (NHANES)[13,14] use a random sample of one maxillary quadrant and one mandibular quadrant with a fixed subset of sites, ranging from two to three sites per tooth. Susin et al.[15] found that PRPs underestimate the prevalence of periodontal disease and that there is considerable variation in the degree of underestimation. Kingman et al.[10] examined PRPs for severity estimates of periodontal disease using the random half-mouth quadrants and various combinations of two to three sites per tooth used by NHANES. They found that three sites per tooth (MB, mid-buccal [B], and disto-lingual) on random half-mouth examination produced relative biases of <3% in absolute value for mean PD and mean AL.

Using the NHANES (1999 to 2002) database,[13] the objective of this study is to evaluate which of the 15 measures of periodontal problems (e.g., maximum AL, mean AL, and cumulative means of AL) best predict the need for periodontal treatment.

MATERIALS AND METHODS

The 1999 to 2000 and 2001 to 2002 subwaves of the NHANES[13] survey were used because of the availability of demographic, behavioral, and clinically determined oral health data, the sufficient power, and the high level of representation and concurrency. NHANES is a program of studies designed to assess the health and nutritional status of adults and children in the United States through a stratified, multi-stage, probability sampling design.

The periodontal examination in NHANES is based on a random half-mouth examination at two sites, B and MB, for each tooth. A maximum of 14 teeth and 28 sites were examined per individual. Periodontal breakdown is measured by AL, which is based on PD and gingival recession (GR). PD is measured from the crest of the free gingival margin (FGM) to the base of the gingival sulcus. GR is measured from the crest of the FGM to the cemento-enamel junction (CEJ). The algebraic difference between PD and GR yields AL.

In the 1999 to 2002 NHANES, periodontal disease measures are available for participants 18 years of age and older. For this paper, three periodontal indices were created using the mid-facial or mesial site or both sites by summarizing ALs across all teeth. The three indices were: 1) the sum of the maximum B and MB measures of AL, which reflects the worst case of both B and MB measures; 2) the sum of the maximum MB measure, or the worst case of the MB measure; and 3) the sum of all B and MB measures, or the cumulative AL measures. As a result, a total of nine continuous measures were created. The cutoff points used for the six categorical measures were 4 and 6 mm. The details of the definition are illustrated in the Results section.

Periodontal needs were based on the professional judgment of the dental examiner at the conclusion of the dental examination. The examiner could choose one or more of the following conditions to indicate the need for dental care: 1) decayed teeth; 2) gum problems/disease; 3) oral hygiene; 4) clinical impression of soft tissue condition; 5) denture/partial denture/plates; 6) no significant findings; and 7) other findings.[15]

Statistical Analyses

Bivariate analysis was performed to compare the different measures of the need for periodontal treatment, and the association among the measures and the need was evaluated. X^2 tests were used to examine differences in proportions. Survey logistic regression models were used to predict clinically determined periodontal needs by dental specialists, taking the complex sampling design into consideration. The outcome measure is the need for periodontal care, which is based on the clinical judgment of the highly trained examining dentists. The predictor measures are each of the 15 AL measures (as shown in Table 1) in turn for each of the 15 models, adjusted for demographic characteristics such as age, education, sex, and ethnicity, as well as smoking status and diabetes. The adjusted odds ratio was derived from the coefficients of the logistic models and the standard errors. The Akaike

Information Criteria (AIC)[17] criterion was used to compare the fitness of the model. AIC is a penalized likelihood that takes into account the number of parameters in a model:

$$AIC = 2k - 2\ln(L),$$

where k is the number of parameters and L is the likelihood. The smallest AIC indicates the best predictive measure. Data were analyzed using statistical software. ‖

RESULTS

The definitions of 15 periodontal disease measures (nine continuous and six categorical) are shown in Table 1. The weighted frequency (percentage) in the population is shown for the categorical measure, and means (standard deviation) are given for the continuous measures.

Table 2 shows the weighted frequency and percentage in the population. There were 7,320 participants (aged 18 to 85 years) in the sample, 3,250 (44%) from the year 1999 to 2000 survey and 4,070 (56%) from the year 2001 to 2002. The combined sample represents 150 million people. The weighted mean age of the sample is 42 years (SD = 0.36). There are four age groups: 1) 16% were 18 to 24 years, 2) 45% 25 to 44, 3) 30% 45 to 64, and 4) 10% ≥65. 50.3% were male. The majority (81%) had an education of high school or above. Regarding ethnicity, 70% were white, followed by Hispanic (15%), African American (10%), and other (5%). Nearly half (47%) were non-smokers, 24% were current cigarette smokers, 23% were previous cigarette users, and 6% smoked other than cigarettes. Regarding diabetes status, 66% of the population did not have diabetes, 23% had pre-diabetes, and 12% had diabetes.

Table 3 shows the three best predictive models selected by AIC from the candidate models. In multivariable logistic model 1, all the covariates except sex were statistically significant for ages 45 to 64 years and 65+, high school or less, African American, current smoker, pre-diabetes, and diabetes. The odds ratio of AL for African Americans versus whites is 1.78; that is, an African American person has a 78% greater chance of AL than a white person. Participants with diabetes have a 49% greater chance of AL than those without diabetes. Current smokers have a 58% greater chance of AL than non-smokers. Compared with people with more than a high school education, those with only a high school education have a 57% greater chance of AL, and people with less than a high school education have double the chance.

DISCUSSION

There is general agreement that the outcome variable for measuring periodontal breakdown is alveolar bone loss or its clinical equivalent, AL.[18] Use of the periodontal probe to measure periodontal breakdown is a routine procedure, but careful consideration of this process is surprisingly complex. Issues that complicate the picture are: 1) the diameter of the probe tip (varies from 0.4 to 0.5 mm); 2) the resolution of a manual probe (1 mm); 3) reproducibility

‖ SAS, v. 9.2, SAS Institute, Cary, NC.

(from ± 0.38 to 1.0 mm); 4) the variability of probing forces, which may vary by regions of the mouth; and 5) the depth of penetration, which is influenced by the health of the gingival tissues (deeper penetration is possible into a diseased periodontal pocket than a healthy gingival sulcus). Physical factors include: 1) the anatomy and alignment of teeth; 2) the absence of teeth that may be due to periodontal disease; 3) the roughness of the root surface; 4) the presence of subgingival calculus; and 5) the comfort level of the patient.

In addition to measurement error, the lack of agreement on the definition of periodontal disease complicates the issue. AL, which is the cumulative past periodontal experience of a person, the equivalent of alveolar bone loss, is considered the gold standard because it uses the CEJ as a fixed reference point, unlike PD measures. However, AL does not reflect active periodontal disease, which is based on pocket measures >4 mm with the presence of bleeding or BOP, a sign of inflammation.

MB and B sites have been used for many years in random half-mouth examinations of periodontal breakdown by the NHANES survey starting in 1988. In the NHANES III Survey (1988 to 1994), Kingman and Albandar[19] found the interclass correlation of AL between MB-B half-mouth examinations and MB-B full-mouth examinations to be 0.99. Sensitivity estimates for AL between MB-B half-mouth and full-mouth examinations were 0.57 and 0.66, respectively, for AL ≥4 mm, and 0.55 and 0.81 for AL ≥6 mm. In a Brazilian population slightly younger than that of the NHANES III Survey, Kingman et al.[10] compared mean scores for AL between MB-B half-mouth (1.07 mm) and MB-B full-mouth (1.17 mm) examinations and found a relative bias of −8.55%. Their study suggested that mean AL scores better reflect the severity of disease than the prevalence of disease using a fixed maximum cutoff value for AL. This was particularly important in studies that investigated associations between periodontal disease and systemic disease.

Of the two sites used in the data analysis, the MB site is more reflective of periodontal breakdown than the B site, which is influenced by brushing habits more than periodontal disease. Of the three best predictive models (Table 3), model 1 was selected as the best because it had the best fit. Taking the maximum score for each site and summing both sites increases the likelihood of identifying severe periodontal breakdown. All the demographic variables and covariates follow the classic pattern of association with periodontal disease that has been observed in previous surveys. Compared with whites or non-smokers, African Americans or current smokers have a higher chance of AL. People with a high school education or less have a much higher chance of AL. Although a lack of laboratory data on diabetes may reduce confidence in the diagnosis of diabetes, individuals with diabetes have a 49% greater chance of having AL than those without.

At the current stage of research, the authors of the present study have determined which periodontal measure best predicts the examiner’s decision to recommend treatment for “gum problem/disease,” which is the sum of the higher level of AL for either the MB or B AL measurement on all teeth present, controlling for the sociodemographic measures used in the analyses. Because the most powerful predictor is the sum of worse AL between MB and B AL across all the teeth present, in dental practice clinicians probably should pay attention to all the teeth a patient has, rather than just the worst-case tooth, to capture periodontal

treatment needs. The clinical relevance is twofold: 1) for current utility, dentists need to pay attention to not only the worse AL between MB and B, but also every tooth (sum), and 2) for future utility, further research can be done to determine a threshold dentists can use to make decisions about the need for periodontal care.

A limitation of this study is the use of random half-mouth examinations, which are known to result in underestimation of true periodontal breakdown. Using only two sites per tooth instead of six also contributes to this underestimation. Despite these limitations, the positive results observed are encouraging in that they suggest the possibility of developing one composite score that captures periodontal breakdown. The large sample size used in this analysis adds credibility to the results.

Validation of the approach will become possible when data from full-mouth examinations at six sites per tooth become available. In addition, the outcome measure is the need for periodontal care, but not specific treatment needs. It would be desirable to have an outcome measure or composite index that better defines the type of periodontal treatment needed. The next phase of this research is to determine the clinically sensitive threshold of the sum of the max AL for either the MB or B AL, by which clinicians can make a decision about periodontal treatment for individual patients.

CONCLUSIONS

Cumulative periodontal morbidity, particularly the worst case of B and MB measures, has the strongest impact on the need for periodontal care. All demographic variables and covariates follow the classic pattern of association with periodontal disease.

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Table 1.

Summary Statistics for the 15 Periodontitis Measures and Clinically Determined Periodontal Need, by AIC From Best to Worst Model

Measure	Variable	Definition	Mean (SD) (continuous) or n (%) (categorical)*	Range
1	Sum AL max	Sum of all maximum MB and B measures	3.46 (0.08)	0 to 32
2	Sum AL sum	Sum of all MB and B measures	15.89 (0.55)	0 to 129
3	MB AL max	Maximum MB measure	1.91 (0.04)	0 to 15
4	MB AL sum	Sum of all MB measures	8.60 (0.29)	0 to 64
5	Sum AL mean	Mean of MB and B measures	1.47 (0.05)	0 to 26
6	MB AL mean	Mean of MB measures	0.79 (0.03)	0 to 14
7	B AL max	Maximum B measure	1.93 (0.05)	0 to 17
8	B AL mean	Mean of B measures	0.68 (0.03)	0 to 12
9	B AL sum	Sum of all B measures	7.39 (0.31)	0 to 72
10	AL ≥4	Whether any B or MB measure is ≥4 mm	29,019,043 (19.4)	0, 1
11	B AL ≥4	Whether any B measure is ≥4 mm	23,838,936 (15.9)	0, 1
12	MB AL ≥4	Whether any MB measure is ≥4 mm	17,582,140 (11.7)	0, 1
13	AL ≥6	Whether any B or MB measure is ≥6 mm	8,718,653 (5.8)	0, 1
14	MB AL ≥6	Whether any MB measure is ≥6 mm	5,916,458 (3.9)	0, 1
15	B AL ≥6	Whether any B measure is ≥6 mm	5,836,006 (3.9)	0, 1
	Dependent variable	No periodontal need	106,876,184 (71.3)	
	Dependent variable	Periodontal need	43,042,015 (28.7)	

Periodontal need was based on the professional judgment of the dental examiner at the conclusion of the dental examination. The MB measure is defined as the *i*th molar mesiofacial AL calculation of (FGM to sulcus base measurement) – (FGM to CEJ measurement) in millimeters; the measure is taken at 28 teeth labeled 2 to 15 and 18 to 31. The B measure is defined as the ith molar midfacial AL calculation of (FGM to sulcus base measurement) – (FGM to CEJ measurement) in millimeters; the measure is taken at 28 teeth labeled 2 to 15 and 18 to 31.

*Measures 1 through 9 are continuous; measures 10 through 15 are categorical (yes or no, represented by 1 or 0, respectively).

Table 2.

Summary Statistics for the Covariates

Variable	Weighted Frequency	%	Periodontal Needs	%
Age (years)				
18 to 24	23,304,292	15.5	5,218,815	22.4
25 to 44	67,503,821	45.0	19,349,647	28.7
45 to 64	44,206,011	29.5	13,630,518	30.8
65+	14,904,074	9.9	4,843,035	32.5
Sex				
Males	75,382,870	50.3	18,191,620	24.1
Females	74,535,328	49.7	24,850,395	33.3
Ethnicity				
Hispanic	22,773,280	15.2	8,317,372	36.5
White	104,882,526	70.0	25,835,450	24.6
African American	15,324,558	10.2	6,328,642	41.3
Other	6,937,834	4.6	2,560,551	36.9
Education				
Less than high school	28,388,080	18.9	13,334,958	47.0
High school	38,064,018	25.4	12,272,271	32.2
More than high school	83,466,100	55.7	17,434,786	20.9
Smoking status				
Non-smoking	71,051,912	47.4	16,739,536	23.6
Smokes other than cigarettes	8,180,451	5.5	2,262,446	27.7
Former cigarette smoker	34,072,902	22.7	9,359,850	27.5
Current cigarette smoker	36,612,933	24.4	14,680,183	40.1
Diabetes status				
No diabetes	48,895,901	65.73	12,692,654	57.6
Pre-diabetes	16,819,042	22.61	5,630,299	25.5
Diabetes	8,673,922	11.66	3,725,370	16.9
Data missing *	75,529,334		20,993,692	
Total	149,918,198	100	43,042,015	28.7

All covariates are significant using Rao-Scott χ^2 test.

*Mainly due to missing laboratory results.

Table 3.

The Three Best Predictive Models

	Model 1		Model 2		Model 3	
	Odds Ratio	***P* value***	**Odds Ratio**	***P* value***	**Odds Ratio**	***P* value***
Predictive measure †						
Sum AL max	1.5534	<0.0001				
Sum AL sum			1.0855	<0.0001		
MB AL max					2.1364	<0.0001
Covariate						
Age						
18 to 24 years			Logistic reference			
25 to 44 years	1.0696	NS	1.2067	NS	1.2534	NS
45 to 64 years	0.6856	0.0148	0.8525	NS	0.9092	NS
65+ years	0.2651	<0.0001	0.4799	0.0025	0.4107	0.0008
Sex						
Males			Logistic reference			
Females	1.1728	NS	1.0285	NS	1.2775	0.0120
Education						
More than high school			Logistic reference			
Less than high school	2.0187	<0.0001	2.3921	<0.0001	1.9494	<0.0001
High school	1.5706	0.0004	1.8873	<0.0001	1.5583	0.0017
Ethnicity						
White			Logistic reference			
Hispanic	1.3438	NS	1.3571	NS	1.2488	NS
African American	1.7800	<0.0001	1.7998	0.0003	1.6157	NS
Other	1.3595	NS	1.4061	NS	1.3650	NS
Smoking status						
Non-smoker			Logistic reference			
Smokes other than cigarettes	1.3266	NS	1.4053	NS	1.4814	NS
Former cigarette smoker	1.0039	NS	1.0078	NS	1.0663	NS

	Model 1		Model 2		Model 3	
	Odds Ratio	***P* value***	**Odds Ratio**	***P* value***	**Odds Ratio**	***P* value***
Current cigarette smoker	1.5770	0.0014	1.6744	0.0008	1.4899	0.0072
Diabetes						
No diabetes			Logistic reference			
Pre-diabetes	1.2853	0.0444	1.3081	0.0356	1.2505	NS
Diabetes	1.4889	0.0234	1.7802	0.0007	1.3878	0.0396
AIC	70714342		70718845		71241184	

* *P* values <0.05 are significant. NS, not significant.

† To predict the event "have clinical periodontal needs."