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The relationship between selected measures of periodontal status and demographic and behavioural risk factors

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Abstract

Objective: To assess differences between selected periodontal measures by demographic and behavioural factors in a nationally representative sample of the United States.

Methods: Data for 11,347 person's ages 20–79 years from the third National Health and Nutrition Examination Survey (NHANES III) were used. Indices and measures constructed from NHANES III data used for this study were: derived community periodontal index (dCPI), attachment loss extent index (ALEI), attachment loss (AL) scores, and a Periodontal Status Measure (PSM) developed for this study.

Results: The influence of demographic and behavioural factors varied across the four indices examined in multivariate cumulative logistic models. Moreover, there was significant effect modification by cigarette smoking with age in the ALEI and AL models. The odds ratio (OR) of increasing periodontal disease status among 20–39 year olds as measured by AL or ALEI for current smokers compared with non-smokers were OR = 6.2 (95% confidence interval (CI) = 4.1, 8.7) and OR = 5.6 (95% CI = 3.7, 8.7), respectively. In a similar comparison, the OR for dCPI was 2.6 (95% CI = 1.7, 3.8). Furthermore, Mexican American ethnicity was generally not significant in any models using dCPI, PSM, AL, or ALEI and prior dental visit was more likely to be significant only in the dCPI and PSM models.

Discussion: Among the well-known demographic and behavioural influences on periodontal health status, some, such as race/ethnicity and prior dental visit status have different relationships with differing periodontal measures employed to assess periodontal status. Moreover, potential interactions among cofactors also are dependent upon the measure selected. Periodontal research findings may be influenced significantly by periodontal measure selection and its affect on measurement validity. This may have particular relevance to issues concerning disease surveillance and assessing reduction of disparities in oral health. Consequently, a renewed approach to developing appropriate measures for periodontal epidemiology is needed.

Key words: dental public health; dental research; epidemiology; ordinal regression; periodontal disease; periodontal indices

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Current methods for measuring periodontal diseases have advanced our knowledge of the disease process in individuals, but our understanding of methodological limitations of various measures for periodontal diseases in applications such as clinical trials, surveys, and other research studies is limited. Although Russell presented the first index to classify the health and disease status of the periodontium more than 40 years ago, consensus has yet to be reached with regard to universal acceptance of an epidemiologic approach for assessing periodontal conditions.

Russell developed the periodontal index (PI) in 1956 in response to earlier proceedings from a periodontal workshop at the University of Michigan that concluded ''the lack of valid indexes for determining the prevalence and epidemiological characteristics of periodontal diseases had hindered seriously the development of more effective preventive and treatment procedures for these

diseases'' (Russell 1956). Russell had stated that the PI had two disadvantages: (1) the index was not useful for the assessment of an individual's periodontal health for treatment planning purposes and (2) implementation of the PI required standardized and calibrated dental examiners. However, another disadvantage that has become evident with time is the reliance on subjective, rather than objective, measurement of the clinical presentation of disease. The PI scores all periodontal pockets $\geqslant 3$ mm the same and inflammation is graded subjectively with no apparent differentiation between gingivitis and periodontitis.

To address some of these issues, Ramfjord (1959) introduced the periodontal disease index (PDI) in 1959. Ramfjord chose six teeth to represent the full dentition to expedite the application of the PDI in the field and to increase the number of subjects examined with the intent to reduce individual sampling variation. Although the PDI never was utilized fully, Ramfjord's six teeth (upper left central incisor and first bicuspid, the upper right first molar, the lower right central incisor and first bicuspid, and the lower left first molar) continued to be used as representative index teeth for various periodontal assessments. The PDI became the first epidemiologic index to use a periodontal probe to measure clinical loss of attachment and this indirect method of measuring clinical attachment loss (AL) is still widely used.

In an attempt to capture the degree of severity and extent of periodontal disease into an index construct, the extent and severity index (ESI) was proposed in 1986 (Carlos et al. 1986). This index uses probing measurements for levels of periodontal loss of attachment to summarize the extent of previous disease activity. Currently, there is a trend towards defining periodontal disease case status for epidemiologic applications by combining probing depth and clinical AL measures; the most severe probing depth and concomitant clinical AL measures from the same site are typically used to produce a threshold definition of disease (Tomar & Asma 2000, Arbes et al. 2001). A less complex process to assess periodontal tissue destruction is to approximate mean bone loss using loss of clinical attachment as a surrogate measure. It has been reported that mean values are beneficial in exploring trends, describing differences in disease severity, and examining relationships between disease and potential predictors, such as oral microbe load or smoking status, and between probed clinical AL and radiographic alveolar bone loss (Okamoto et al. 1988, Haffajee et al. 1995, Pilgrim et al. 2000, Haffajee & Socransky 2001).

In the 1970s, indices were being developed to address interests in assessing periodontal treatment needs. The first systematic method to classify periodontal treatment needs, the periodontal treatment needs system (PTNS), was presented in 1973 (Johansen et al. 1973). This index classified need into three categories – oral hygiene instruction, scaling, and periodontal surgery – and estimated therapeutic time for each unit of need. Building upon the PTNS, the Community Periodontal Index (CPI) of Treatment Needs (CPITN) was developed in the late 1970s. The CPITN was endorsed by the World Health Organization (WHO) for population-based surveys in the early 1980s (Ainamo et al. 1982) but was later renamed by WHO as the CPI to foster its use as an index to measure periodontal status in populations (WHO 1997). Initial recommendations for the implementation of CPITN included the use of a special periodontal probe (WHO probe), the use of six index teeth (first molars and right central incisors), and the division of periodontal pockets into moderate and more severe categories. The quadrants used for PTNS were replaced with sextants for scoring purposes. CPITN is more accurate in assessing periodontal diseases and treatment needs compared with the PI (Cutress et al. 1986) but the use of CPITN index teeth underreports prevalence (Ainamo and Ainamo 1985).

The CPITN has been widely used internationally but the application of the index in the US has been limited. In 1992, the American Academy of Periodontology introduced the periodontal screening and recording (PSR) procedure for use in the US The PSR is a CPITN-based PI designed to detect disease within individuals (Nasi 1994). Although PSR has not been promoted widely for use in population-based surveys and surveillance activities, it has been used to estimate periodontal health status in a US military population (Covington et al. 2003).

Differing approaches exist in measuring disease status, which produce inconsistency in study design (Irfan et al. 2001). The need for reliable and valid periodontal indices recently has grown as researchers elucidate the complex etiology and pathogenesis of periodontal diseases and the relationship between systemic and periodontal infections. Moreover, indices and summary measures are needed for continued periodontal disease surveillance in populations and for the conduct of clinical trials. To understand better the relationship among different periodontal measurement approaches, this study used nationally representative data to compare and contrast several constructed periodontal summary measures. By examining differences among these summary measures as well as differences between the relationship of these measures with socio-demographic and lifestyle behaviour risk factors, we aim to understand better the use and limitations of these periodontal measures, which potentially could identify characteristics for future measures and indices.

Methods

Study population

Data from 11,347 people who participated in the third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III), were used. Conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention, NHANES III utilized a complex, highly stratified, multistage probability design capable of producing a nationally representative sample. Details of the sample design and methods used in obtaining informed consent from study participants have been described elsewhere (CDC 1992, 1994). NHANES III over sampled individuals who were either under the age of 6 or over the age of 60, Mexican Americans, and non-Hispanic blacks. This was done to enhance the reliability of prevalence estimates for these groups in the non-institutionalized civilian population of the US. For this study, data were obtained from the household interview questionnaire and a standardized oral health examination. Trained dentists conducted the dental examinations in mobile examination centers (MEC), and the survey's expert examiner periodically calibrated the examiners.

Among the 31,311 participants who had an examination visit to the MEC, we excluded 1122 individuals who had no dental examination data. Then 13,196

individuals were excluded because they were either under 20 years or older than 79 years. Individuals aged 80 years or older were excluded from the analyses because less than 40% of these individuals had six teeth or more and had completed a periodontal examination. Persons under 20 years were excluded because of relatively low prevalence of periodontal disease. From this remaining group, 1426 persons were excluded for having five teeth or less and lacking a completed periodontal examination. An additional 4220 persons with incomplete education and dental visit frequency information were excluded to yield a study population of 11,347 persons. Reasons for a non-completed periodontal examination include medical exclusions for health reasons, refusal to complete any portion of the periodontal examination (thus producing a partial examination), and other reasons. Health concerns that required the use of antibiotics before the periodontal examination represented the majority of medical exclusions.

Outcome variables

The outcome variables examined in this analysis were constructed PI or summary measure variables. These were Attachment Loss Extent Index (ALEI), Periodontal Status Measure (PSM), AL, and a derived CPI (dCPI). PI information was derived from examination data collected for calculus, bleeding, probing depth, clinical AL, and furcation status. Periodontal assessments in NHANES III were made at two consistent facial sites on each fully erupted permanent tooth, except third molars, in two randomly selected quadrants (i.e., one maxillary and one mandibular). Periodontal measurements were truncated to the whole millimetre and were made with a 2 mm graduated periodontal probe. Detailed information about the NHANES III oral health component protocol, quality control, and measurement issues have been described elsewhere (CDC 1994, Drury et al. 1996, Winn et al. 1999).

A person's dCPI score was based on WHO scoring criteria and was derived from the worst tooth condition observed for each quadrant using the CPIs inherent hierarchical assumptions. For instance, if a tooth had any evidence of bleeding, but no calculus or probing depths of 4 mm or more, then that tooth was scored a ''1''. If a tooth had any probing depths of 6 mm or more, then that tooth was scored a ''4''. This study's dCPI scoring guidelines used probing depth measurements as specified by Ainamo in 1994 for CPITN (Ainamo & Ainamo 1994) and by WHO for CPI (WHO 1997). A dCPI subject-level score was determined by the selection of the worse of the two quadrant scores. The dCPI numerical scores and their corresponding clinical presentations are presented in Table 1.

For the ALEI score, the number of dental sites per person affected by clinical AL was summed, divided by the number of dental sites evaluated, and multiplied by 100. This percentage was categorized into five groups: 0–4% of sites affected, 5–24% of sites affected, 25–49% of sites affected, 50–74% of sites affected; and 75% or more of sites affected. Clinical AL, as an indicator of past periodontal disease, was defined as a minimum of 2 mm of measured loss. These criteria were established to reflect a previously published AL extent and severity index (Carlos et al. 1986). The clinical descriptions for ALEI are presented in Table 1.

For the AL score, clinical AL measured in millimetres at each dental site was summed and divided by the number of sites examined to produce a mean clinical AL score. This score was categorized into five groups: 0–1 mm of average clinical AL, 1.1–1.5 mm of average clinical AL, 1.6–2.0 mm clinical AL, 2.1–2.5 mm of average clinical AL, and 2.6 mm or more average clinical AL. These five categories were chosen based on findings from a preliminary data analysis that identified distinctive inflection points on a curve when severity of clinical AL was plotted against extent of clinical AL. Clinical considerations for AL are presented in Table 1.

A person's PSM score was derived based on the worst tooth condition observed for each quadrant. Then the overall PSM score was determined by the selection of the worse of the two quadrant scores. The PSM scoring range of 0–4 is similar to CPI, but unlike the CPI, the PSM incorporates clinical AL

Table 1. Description of clinical presentation for periodontal status measures: ALEI, AL, dCPI, and PSM

Measure	ALEI	AL	dCPI	PSM
0	0–4% of sites with 2 mm or more of clinical AL	0–1 mm average amount of clinical AL	Healthy (no bleeding, calculus, or probing depth $\geqslant$4 mm)	Healthy (no bleeding or clinical AL)
1	5–24% of sites with 2 mm or more of clinical AL	1.1–1.5 mm average amount of clinical AL	Bleeding with probing is present	Gingivitis (bleeding is present, probing depth $<$3 mm, clinical AL $\leqslant$1 mm)
2	25–49% of sites with 2 mm or more of clinical AL	1.6–2.0 mm average amount of clinical AL	Calculus is present (supra-or subgingival)	Mild periodontitis (at least one site with a probing depth 3–4 mm, clinical AL 2–3 mm, no furcations)
3	50–74% of sites with 2 mm or more of clinical AL	2.1–2.5 mm average amount of clinical AL	At least one site with a probing depth 4–5 mm	Moderate periodontitis (at least one site with a probing depth 5–6 mm, clinical AL 4–5 mm, may have a class I furcation)
4	75–100% of sites with 2 mm or more of clinical AL	2.6+ mm average amount of clinical AL	At least one site with a probing depth 6 mm or more	Advance periodontitis (at least one site with a probing depth $>$6 mm, clinical AL $>$5 mm, may have a class I or II furcation)

ALEI, attachment loss extent index; AL, attachment loss; dCPI, derived community periodontal index; PSM, periodontal status measure.

and dental furcation status into the index. The PSM numerical scores and their corresponding clinical presentations are presented in Table 1.

Covariate selection

For this analysis, we included indicators that have been reported to be associated with oral health. Race/ethnicity was categorized as Mexican American, non-Hispanic black, non-Hispanic white, and other. Individuals who were identified as ''others'' were included in the total population estimates but not in the regression analyses. Education was categorized as not completed high school, completed high school, and at least some college experience. Past dental history was dichotomized as either having had a dental visit within the past 12 months or not. Age was categorized into three groups: 20–39 year olds, 40–59 year olds, and 60–79 year olds. Cigarette smoking status was categorized as either current smoker, former smoker, or never smoked. Persons who reported that they had smoked at least 100 cigarettes (approximately five packs) in their lifetime but no longer smoke were classified as a ''former smoker.''

Data Analysis

All statistical analyses were performed with SUDAAN, a software package that is designed specifically to accommodate complex sample surveys (Shah et al. 1997). Sample weights were used to account for the unequal probability of selection and non-response of the study participants to produce prevalence estimates, relative odds ratio (OR), and related standard errors. Bivariate analyses of periodontal parameters, sociodemographic characteristics and smoking status were conducted. The MULTILOG function within SUDAAN was used to compute proportional ORs. This cumulative logistic function uses an ordinal categorical outcome variable of two or more categories to produce a proportional odds model. Alternatively, the basic logistic function uses a dichotomous outcome variable to produce a binary logistic model.

Because the ranked PI scores are more reflective of an ordinal scale instead of a nominal scale, ordinal regression was used to account for the qualitative magnitude between categories for each PI score. Detailed description of ordinal regression for health outcomes has been described elsewhere (Scott et al. 1997). Cumulative logistic models have been used in the assessment of risks for periodontal diseases (Grossi et al. 1995, Hyman & Reid 2003) and in estimating periodontal status in the United States (Dye & Vargas 2002).

Proportional odds models were used to estimate adjusted ORs and 95% confidence intervals (CI). The index scores of dCPI, ALEI, AL, and PSM were modeled as the dependent variables. Each of these PI scores was derived by algorithms written in SAS (SAS Institute 1999). All independent variables were modeled categorically as described previously. Non-automated regression modeling was used to assess the relationships between the covariates. Potential interactions were explored throughout the modeling process.

Results

The population characteristics and periodontal clinical parameters for this study group of 11,347 adults are presented in Table 2. The distribution of the study population by sociodemographic characteristics, smoking status, and frequency of dental visit, according to PI scores, is presented in Table 3. Individual ages 60–79 years were more likely to have the most severe ALEI score (30.9%). Adult ages 20–39 years were more likely to have minimal clinical AL extent of 0–4% (42.0%). Overall 30.2% of the study group had an ALEI score of 0; 27% and another 17% scored a 1 and 2 in the ALEI categories, respectively; and 12.9% had ALEI scores of 3 and 4, respectively.

A dCPI score of 2 was the most prevalent among all sociodemographic

Table 2. Selected characteristics of adults aged 20–79 years from NHANES III, 1988–1994

Category	Sample size	Weighted percent (SE)
Sex		
Males	5384	49.3 (0.52)
Females	5963	50.7 (0.52)
Age (years)		
60–79	1903	12.2 (0.74)
40–59	3225	30.9 (0.73)
20–39	6219	56.9 (1.02)
Race/ethnicity		
Mexican American	3631	6.04 (0.53)
Non-hispanic black	3290	11.1 (0.64)
Non-hispanic white	3948	74.5 (1.31)
Other	478	8.40 (0.85)
Educational attainment		
Did not complete high school	3940	19.2 (0.92)
Completed high school	3684	33.7 (0.85)
At least some college experience	3723	47.2 (1.27)
Smoking status		
Current smoker	3026	28.1 (0.83)
Former smoker	2401	23.0 (0.57)
Never smoked	5919	48.9 (0.84)
Had dental visit within past 12 months		
Yes	6911	69.4 (0.88)
No	4436	30.6 (0.88)
Had any calculus present		
Yes	668	7.90 (1.05)
No	10679	92.1 (1.05)
Had any bleeding present		
Yes	6766	52.5 (2.29)
No	4581	47.5 (2.29)
Periodontal probing depth prevalence		
At least one pocket 6+ mm	578	3.10 (0.29)
At least one pocket 4–5 mm	2904	19.4 (1.39)
All measurable pockets $\leqslant$3 mm	7865	77.5 (1.60)
Clinical attachment loss prevalence		
At least one site 5+ mm	1907	13.0 (0.64)
At least one site 3–4 mm	3169	27.7 (0.71)
At least one site 1–2 mm	6018	56.9 (1.00)
No sites with clinical attachment loss	253	2.40 (0.46)

SE, standard error; NHANES III, third National Health and Nutrition Examination Survey.

Table 3. Description of selected characteristics by (a) ALEI and dCPI scores and (b) AL and PSM scores [percent present with standard error (SE)] for adults aged 20–79 years in the United States, 1988–1994

Measure	ALEI					dCPI				
	0	1	2	3	4	0	1	2	3	4
(a)										
Total	30.2 (1.40)	27.0 (0.88)	17.0 (0.52)	12.9 (0.69)	12.9 (1.06)	4.60 (0.71)	2.60 (0.45)	70.3 (1.99)	19.4 (1.39)	3.10 (0.29)
Sex										
Male	26.6 (1.53)	24.9 (1.10)	17.2 (0.66)	14.4 (0.90)	16.9 (1.33)	3.50 (0.70)	2.40 (0.44)	67.7 (1.91)	22.4 (1.46)	4.10 (0.43)
Female	33.6 (1.60)	29.1 (1.14)	16.8 (0.81)	11.5 (0.93)	9.00 (0.90)	5.70 (0.84)	2.80 (0.54)	73.0 (2.25)	16.5 (1.51)	2.10 (0.27)
Age (years)										
20–39	42.0 (1.89)	29.2 (1.09)	13.8 (0.81)	8.20 (0.79)	6.80 (0.97)	4.90 (0.84)	2.70 (0.48)	71.1 (2.02)	19.3 (1.52)	2.10 (0.28)
40–59	17.0 (1.28)	26.1 (1.36)	21.0 (0.90)	18.2 (1.22)	17.6 (1.23)	4.30 (0.81)	2.40 (0.63)	69.9 (2.16)	19.4 (1.39)	4.00 (0.50)
60–79	5.70 (1.29)	18.2 (1.71)	22.7 (1.30)	22.5 (1.37)	30.9 (2.76)	4.10 (0.82)	2.70 (0.63)	68.0 (3.10)	19.4 (2.42)	5.60 (0.86)
Race/ethnicity										
Mexican American	32.2 (2.24)	28.5 (1.67)	15.6 (0.93)	12.5 (1.06)	11.3 (1.76)	2.20 (0.61)	1.50 (0.33)	67.5 (1.52)	25.3 (1.28)	3.50 (0.42)
NH black	28.5 (1.41)	25.6 (0.99)	16.3 (0.77)	13.8 (0.67)	15.9 (1.41)	2.70 (0.64)	1.00 (0.32)	57.3 (2.28)	32.0 (1.80)	7.00 (0.56)
NH white	31.2 (1.62)	27.0 (0.97)	17.0 (0.64)	12.4 (0.78)	12.4 (1.10)	5.40 (0.88)	3.10 (0.58)	72.1 (2.38)	17.1 (1.66)	2.40 (0.33)
Education level										
Not completed HS	20.1 (1.88)	23.1 (1.65)	19.1 (1.16)	15.7 (1.03)	22.1 (2.02)	1.70 (0.43)	1.90 (0.41)	62.1 (2.22)	26.9 (1.72)	7.50 (0.78)
Completed HS	30.0 (1.40)	26.4 (1.27)	16.9 (0.88)	13.1 (1.01)	13.6 (1.03)	4.10 (0.71)	1.90 (0.43)	69.3 (2.19)	21.5 (1.80)	3.10 (0.40)
Some college	34.3 (1.81)	28.9 (1.37)	16.3 (0.70)	11.7 (1.24)	8.80 (1.12)	6.10 (1.12)	3.40 (0.78)	74.4 (2.25)	14.8 (1.42)	1.30 (0.23)
Smoking status										
Current	23.8 (1.74)	25.4 (1.40)	15.9 (0.98)	15.0 (1.29)	19.9 (1.50)	2.90 (0.65)	*	64.3 (2.54)	26.8 (2.12)	5.20 (0.65)
Former	22.1 (1.89)	23.7 (1.18)	20.9 (1.45)	16.8 (1.25)	16.6 (1.57)	4.40 (1.09)	2.60 (0.62)	70.0 (2.53)	19.4 (1.62)	3.50 (0.55)
Never	37.5 (1.63)	29.5 (1.21)	15.9 (0.72)	9.90 (0.76)	7.20 (1.02)	5.60 (0.82)	3.60 (0.67)	74.0 (1.87)	15.1 (1.23)	1.70 (0.23)
A dental visit in past 12 months										
No	29.7 (1.61)	25.8 (1.08)	16.8 (1.13)	14.0 (1.07)	13.7 (1.30)	1.60 (0.48)	1.40 (0.32)	66.7 (1.67)	25.8 (1.51)	4.60 (0.43)
Yes	30.4 (1.61)	27.5 (1.14)	17.1 (0.67)	12.4 (0.81)	12.6 (1.16)	5.90 (0.91)	3.20 (0.56)	72.0 (2.31)	16.5 (1.57)	2.50 (0.32)
	AL					PSM				
	0	1	2	3	4	0	1	2	3	4
(b)										
Total	65.6 (2.14)	17.6 (1.28)	8.20 (0.65)	3.80 (0.33)	4.80 (0.37)	43.3 (2.29)	27.1 (1.32)	15.9 (0.97)	7.20 (0.55)	6.50 (0.43)
Sex										
Male	60.1 (2.35)	18.6 (1.48)	9.70 (0.89)	4.90 (0.49)	6.70 (0.55)	37.7 (2.19)	26.0 (1.44)	18.6 (1.18)	8.90 (0.65)	8.70 (0.65)
Female	70.9 (2.06)	16.7 (1.27)	6.70 (0.58)	2.80 (0.34)	2.90 (0.34)	48.7 (2.54)	28.2 (1.46)	13.2 (1.11)	5.60 (0.64)	4.40 (0.43)
Age (years)										
20–39	79.7 (2.23)	13.3 (1.53)	4.40 (0.67)	1.40 (0.28)	1.20 (0.25)	44.4 (2.58)	33.3 (1.91)	15.1 (1.25)	4.60 (0.56)	2.50 (0.38)
40–59	52.7 (2.33)	23.6 (1.67)	11.2 (0.99)	5.40 (0.67)	7.10 (0.74)	43.6 (2.20)	20.3 (1.36)	17.5 (1.10)	9.50 (0.84)	9.10 (0.70)
60–79	32.6 (2.90)	22.9 (1.45)	18.0 (1.71)	10.7 (1.08)	15.8 (1.62)	37.0 (3.05)	15.4 (1.66)	15.2 (1.59)	13.9 (1.56)	18.6 (1.71)
Race/ethnicity										
Mexican American	68.9 (4.02)	16.6 (2.50)	8.30 (1.32)	2.70 (0.33)	3.50 (0.28)	30.0 (2.10)	33.9 (1.59)	21.3 (1.97)	9.10 (0.63)	5.80 (0.52)
NH black	62.3 (2.39)	16.6 (1.16)	9.00 (0.91)	5.30 (0.47)	6.80 (0.47)	32.1 (1.82)	26.9 (1.65)	19.8 (0.94)	10.8 (0.63)	10.4 (0.72)
NH white	66.7 (2.30)	17.7 (1.42)	7.50 (062)	3.50 (0.37)	4.60 (0.46)	46.9 (2.69)	26.4 (1.47)	14.8 (1.20)	6.30 (0.63)	5.70 (0.52)
Education level										
Not completed HS	52.8 (2.89)	18.7 (1.48)	12.3 (1.25)	6.50 (0.77)	9.80 (0.91)	29.6 (2.04)	24.5 (2.58)	22.0 (1.49)	12.0 (1.16)	11.9 (0.85)
Completed HS	64.3 (2.30)	18.4 (1.70)	8.90 (0.72)	3.50 (0.36)	5.00 (0.48)	41.8 (2.85)	27.2 (1.96)	16.2 (1.21)	8.60 (0.85)	6.30 (0.58)
Some college	71.7 (2.66)	16.7 (1.71)	6.00 (0.80)	2.90 (0.42)	2.60 (0.31)	49.9 (2.45)	28.1 (1.65)	13.2 (1.13)	4.40 (0.48)	4.50 (0.39)
Smoking status										
Current	57.6 (2.42)	18.6 (1.35)	10.0 (1.15)	5.40 (0.57)	8.40 (0.83)	41.5 (2.71)	21.5 (1.58)	17.3 (1.52)	10.0 (1.13)	9.70 (0.93)
Former	55.1 (2.44)	22.9 (1.86)	10.8 (0.75)	5.10 (0.72)	6.10 (0.85)	42.7 (2.40)	22.0 (1.40)	17.9 (1.37)	8.80 (0.71)	8.60 (1.12)
Never	75.1 (2.27)	14.6 (1.41)	5.90 (0.83)	2.30 (0.30)	2.10 (0.26)	44.5 (2.46)	32.8 (1.73)	14.1 (0.89)	4.90 (0.54)	3.70 (0.39)
A dental visit in past 12 months										
No	65.2 (2.08)	17.3 (1.31)	8.40 (0.83)	3.40 (0.48)	5.70 (0.54)	35.2 (2.22)	28.5 (1.64)	19.4 (1.38)	9.20 (0.78)	7.60 (0.61)
Yes	65.7 (2.36)	17.8 (1.40)	8.10 (0.78)	4.00 (0.34)	4.40 (0.42)	46.8 (2.63)	26.5 (1.45)	14.3 (1.04)	6.40 (0.64)	6.00 (0.47)

$N = 11347$. *Estimates do not meet the standard for reporting (RSE is $>30\%$ of the estimate).

ALEI, attachment loss extent index; AL, attachment loss; dCPI, derived community periodontal index; PSM, periodontal status measure; NH, non-hispanic; RSE, relative standard error.

Table 4. The weighted percent present with SE for ALEI by other periodontal measure (dCPI, PSM, and AL) scores for adults aged 20–79 years in the United States, 1988–1994

Measure	ALEI				
	0–4%	5–24%	25–49%	50–74%	75–100%
dCPI					
0	37.5 (3.91)	35.0 (3.61)	17.8 (2.37)	7.00 (2.08)	*
1	42.0 (4.42)	36.4 (4.33)	12.1 (3.19)	5.69 (1.78)	*
2	35.3 (1.64)	28.6 (1.13)	16.3 (0.83)	11.1 (0.85)	8.80 (0.89)
3	12.8 (1.73)	21.2 (1.67)	21.0 (1.41)	20.7 (1.78)	24.4 (1.97)
4	*	6.20 (1.68)	12.2 (3.04)	21.9 (2.75)	59.3 (3.93)
PSM					
0	37.7 (1.81)	30.0 (1.28)	15.1 (0.95)	10.1 (1.10)	7.10 (1.11)
1	50.0 (2.03)	32.3 (1.62)	12.5 (1.21)	4.30 (0.81)	*
2	0.00 (0.00)	28.9 (2.12)	32.7 (1.70)	24.8 (1.88)	13.7 (1.83)
3	*	6.20 (1.30)	19.4 (2.20)	29.6 (2.12)	44.9 (2.91)
4	0.00 (0.00)	1.40 (0.27)	8.40 (1.60)	21.5 (1.96)	68.8 (2.61)
AL					
0	45.3 (1.40)	39.1 (0.92)	14.0 (0.68)	1.50 (0.28)	0.00 (0.00)
1	0.00 (0.00)	5.50 (1.08)	42.2 (1.60)	45.3 (1.73)	7.00 (1.01)
2	0.00 (0.00)	*	3.00 (0.68)	38.0 (2.87)	59.0 (2.72)
3	0.00 (0.00)	0.00 (0.00)	*	18.9 (2.82)	79.3 (3.51)
4	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	5.00 (1.52)	95.0 (1.52)

*Estimates do not meet standards for reporting (RSE > 30% of the estimate).
ALEI, attachment loss extent index; AL, attachment loss; dCPI, derived community periodontal index; PSM, periodontal status measure; SE, standard error; RSE, relative standard error.

characteristics. Men were more likely to have a score of 3 or 4 compared with women. Educational attainment was an important indicator of potential treatment needs. Individuals not completing high school had the highest prevalence of a dCPI score of 4 (7.5%). Individuals with a dCPI score of 0 were more likely to have had a dental visit in the past 12 months (5.9%) compared with those who did not (1.6%). Overall, 70% of the study group had a dCPI score of 2, 19.4% had a score of 3, 4.6% had a score of 0, 2.6% had a score of 1, and about 3% had a score of 4 (at least one site with a probing depth of 6 mm or more).

About 65% of the study group had an AL score of 0, 17.6% had a score of 1, 8.2% scored a 2, and nearly 5% scored a 4 (average clinical loss of attachment greater than 2.5 mm). Nearly 80% of adults 20–39 years scored a 0 compared with 33% of adults aged 60–79 years. Adults, who experienced the greatest average clinical loss of attachment, were more likely to be men, non-Hispanic black, individuals not completing high school, current smokers, and persons between the ages of 60–79 years.

Among the participants who had a dental visit within the past 12 months, nearly 47% had a PSM score of 0 (health). Age and educational attainment were important indicators of advanced periodontitis (PSM score of 4). About 12% of those not completing high school and 19% of those aged 60–79 years had a PSM score of 4. Adults more likely to have a PSM score greater than 1, were less likely to be women, non-Hispanic white, to have at least some college experience, and to have had a dental visit in the past 12 months. Overall, 6.5% of the study population had a PSM score of 4, 7.2% had a score of 3, 15.9% and 27.1% had a score of 2 and 1, respectively, and 43.3% had a PSM score of 0.

Table 4 presents the results of a bivariate analysis comparing dCPI, AL, and PSM to ALEI scores. Among the index scores used to identify periodontal health, 45% of individuals with an AL score of 0 had an ALEI score in the range of 0–4% as compared with 37.5% with a dCPI score of 0 and nearly 38% with a PSM score of 0. Examining index scores used to classify advanced periodontal disease or potential treatment need, 95% of individuals with an AL score of 4 had an ALEI sore in the range greater than 74% as compared with 69% with a PSM score of 4% and 59% with a dCPI score of 4.

Figure 1 presents a graph of the mean percent of AL extent (2 mm) by ALEI, dCPI, PSM, and AL scores. Among those with index scores of 0, the mean loss of clinical attachment extent was nearly 10% for AL, 20% for PSM and dCPI, and less than 1% for ALEI. For those index scores representing the worst category (4), the mean loss of clinical attachment extent was 75% for the dCPI, 80% for the PSM, 89% for the ALEI, and 94% for the AL. The greatest differences in mean loss of clinical attachment extent occurred in the mid-range of index scores (1–3). For instance, when dCPI, ALEI, PSM, and AL scores were a 2, the mean loss of clinical attachment extent varied from 23% to 35%, 42%, and 75%, respectively.

Results from cumulative logistic modeling are shown in Table 5. These regression models demonstrate that increasing severity of the periodontal condition was significantly associated ($p < 0.05$) with older age, lower educational attainment, having smoked cigarettes, being male or being non-Hispanic black. Having a dental visit in the past 12 months was significant only in the dCPI and PSM models. An interaction between age and smoking status was found for ALEI, AL, and PSM during the modeling process. This interaction was not statistically significant ($p > 0.05$)

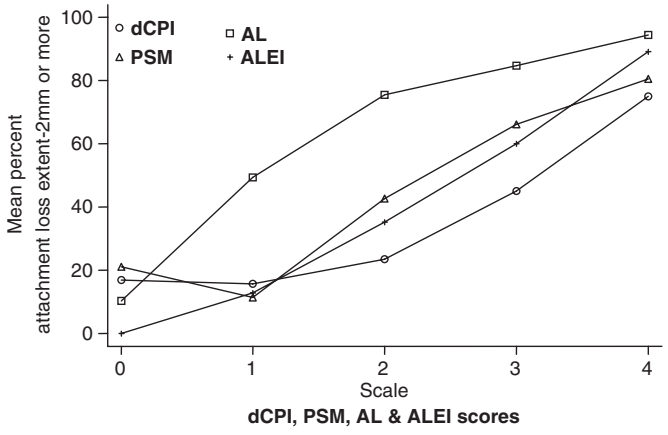

Fig. 1. Mean percent of attachment loss extent for persons with corresponding periodontal measure scores for adults aged 20–79 years in the United States, 1988–1994.

Table 5. OR and 95% CI for the periodontal models controlling for all independent covariates

Model category	OR (CI)			
	PSM model	ALEI model	AL model	dCPI
Sex				
Males	1.54 (1.39–1.72)	1.72 (1.53–1.93)	1.46 (1.28–1.66)	1.64 (1.49–1.80)
Females	1.00	1.00	1.00	1.00
Age (years)				
60–79	9.57 (7.64–12.0)	13.4 (10.5–17.0)	1.62 (1.32–1.98)	2.91 (2.24–3.77)
40–59	3.94 (3.45–4.50)	4.60 (3.83–5.53)	1.30 (1.11–1.53)	1.53 (1.36–1.71)
20–39	1.00	1.00	1.00	1.00
Race/ethnicity				
Mexican American	0.96 (0.70–1.31)	0.94 (0.58–1.52)	1.33 (1.05–1.69)	1.33 (1.07–1.66)
NH black	1.45 (1.15–1.82)	1.58 (1.22–2.06)	2.47 (1.95–3.12)	1.88 (1.56–2.27)
NH white	1.00	1.00	1.00	1.00
Education attainment				
Did not complete high school	2.01 (1.54–2.63)	2.39 (1.74–3.27)	2.03 (1.61–2.57)	2.19 (1.77–2.70)
Completed high school	1.24 (1.06–1.45)	1.45 (1.15–1.83)	1.41 (1.16–1.71)	1.41 (1.22–1.64)
At least some college experience	1.00	1.00	1.00	1.00
Smoking status				
Current smoker	2.69 (2.35–3.08)	3.03 (2.53–3.61)	2.00 (1.74–2.30)	1.34 (1.13–1.59)
Former smoker	1.74 (1.52–2.01)	1.80 (1.56–2.09)	1.36 (1.14–1.63)	1.20 (1.03–1.40)
Never smoked	1.00	1.00	1.00	1.00
A dental visit in the past 12 months				
No	1.02 (0.87–1.18)	1.02 (0.86–1.22)	1.73 (1.46–2.04)	1.39 (1.18–1.64)
Yes	1.00	1.00	1.00	1.00

(1): These models were produced using cumulative logistic regression for adults 20–79 years.

(2): All covariates were present in each of the models.

(3): The independent reference groups were individuals aged 20–39 years, females, NH whites, persons with at least some college experience, and individuals having had a dental visit in the past 12 months.

ALEI, attachment loss extent index; AL, attachment loss; dCPI, derived community periodontal index; PSM, periodontal status measure; OR, odds ratio; CI, confidence interval; NH, non-hispanic.

for dCPI and no other interactions were found. As a result of the smoking and age interaction, an analysis was performed stratified by age and the results are presented in Table 6.

Smoking and lower education attainment continued to be very strong indicators for increasing severity and extent of AL. Current smokers who were 20–39 years of age were more than 5 times as likely to have increasing periodontal clinical AL extent (ALEI) and severity (AL) compared with non-smokers of the same age. The best indicator of increasingly poor periodontal health as measured by the AL among 60–79 year olds was not completing high school (OR = 3.9; 95% CI = 1.9, 7.9) and among 20–39 years old was smoking cigarettes (OR = 6.2; 95% CI = 4.1, 9.4). Not having a dental visit in the past 12 months or being Mexican American was not significant in the stratified analysis for ALEI and AL measures. Being non-Hispanic black was statistically significant ($p > 0.05$) for all age groups using both ALEI and AL indices except for those 60–79 years.

Being non-Hispanic black and not completing high school were the best indicators of increasing severity of periodontal status as measured by the dCPI. Among those aged 60–79 years old, non-Hispanic blacks were 3 times more likely to have increasingly poor periodontal health compared with non-Hispanic whites (OR = 3.1, 95% CI = 2.2, 4.3). Also, not having a dental visit in the past 12 months was associated with increasingly poor periodontal health among all age groups. Lower educational attainment and being non-Hispanic black were associated with increasingly poor periodontal health as measured by the PSM. Not completing high school was the best indicator for increasingly poor periodontal health as measured by the PSM among 60–79 year olds (OR = 2.7; 95% CI = 1.8, 4.3) and among 20–39 years old (OR = 2.9; 95% CI = 1.9, 4.2).

Discussion

In this analysis of more than 11,000 persons representative of the US population aged 20–79 years, we found that among the widely accepted socio-demographic and behavioural indicators for periodontal health, some, such as age, race/ethnicity, and prior dental visit characteristics, are affected by the type of periodontal measures employed to assess disease status. Furthermore, we found that the choice of a PI measure when applied to the data also significantly modulates the effects of age and smoking status as part of an interaction product in statistical models. These findings are an important consideration for researchers in periodontology and epidemiology, and oral health policy makers.

Although our findings suggest that some demographic and behavioural factors influence periodontal outcome measures differently, the finding that a significant interaction exists between age and smoking status for some periodontal indices is very important (Table 6). Smoking produces a synergistic effect with age when ALEI and AL are used to measure disease status. The results of our stratified analysis indicate that the effect modification by current smoking with age on increasing periodontal disease status is present only in the measures that use AL as a periodontal parameter for assessment (ALEI and AL). This heterogeneity of effect is diminished when an index comprised of only probing depth (dCPI) or both clinical AL and periodontal probing depth parameters (PSM) is used. Our analyti-

Table 6. OR and 95% CI for individual periodontal models (ALEI, AL, dCPI, PSM) stratified by age and controlling for independent covariates

Index	Age stratum (years)	Male	Mexican American	Non-hispanic black	Not completed high school	Completed high school	Current smoker	Former smoker	No dental visit past 12 months
ALEI									
	60–79	1.4 (1.1–1.7)	1.0 (0.7–1.7)	1.3 (1.0–1.8)	2.2 (1.4–3.6)	1.3 (1.0–1.6)	1.8 (1.4–2.3)	1.2 (0.8–1.7)	1.1 (0.8–1.4)
	40–59	1.7 (1.3–2.3)	0.9 (0.6–1.2)	1.5 (1.2–2.0)	2.2 (1.5–3.3)	1.2 (0.9–1.5)	2.6 (1.9–3.4)	1.5 (1.1–2.0)	1.1 (0.8–1.5)
	20–39	1.5 (1.2–2.1)	0.9 (0.6–1.4)	1.4 (1.1–1.9)	2.9 (1.7–4.9)	1.5 (1.1–2.1)	5.6 (3.7–8.7)	2.2 (1.7–2.8)	1.0 (0.8–1.3)
AL									
	60–79	1.5 (1.1–2.1)	1.1 (0.4–2.8)	1.6 (1.0–2.7)	3.9 (1.9–7.9)	1.8 (1.2–2.8)	1.6 (1.1–2.3)	1.2 (0.7–2.1)	0.9 (0.6–1.3)
	40–59	1.8 (1.5–2.3)	0.8 (0.4–1.3)	1.5 (1.1–2.0)	2.8 (1.7–4.7)	1.4 (1.0–2.1)	2.4 (1.7–3.2)	1.3 (1.0–1.8)	1.2 (0.9–1.6)
	20–39	1.7 (1.2–2.3)	0.9 (0.6–1.4)	1.7 (1.2–2.3)	3.3 (2.0–5.5)	1.6 (1.0–2.6)	6.2 (4.1–9.4)	2.4 (1.7–3.3)	0.9 (0.7–1.2)
dCPI									
	60–79	1.6 (1.3–2.0)	1.2 (0.8–1.8)	3.1 (2.2–4.3)	2.5 (1.7–3.7)	1.7 (1.3–2.3)	1.4 (1.0–1.9)	1.7 (1.2–2.4)	1.8 (1.3–2.4)
	40–59	1.3 (1.0–1.6)	1.3 (0.9–1.9)	2.2 (1.6–3.0)	2.0 (1.3–3.2)	1.3 (0.9–1.9)	2.4 (1.8–3.2)	1.4 (0.9–2.0)	1.9 (1.4–2.6)
	20–39	1.7 (1.3–2.3)	1.5 (1.1–2.2)	2.5 (1.8–3.4)	2.7 (1.6–4.6)	1.6 (1.1–2.5)	2.6 (1.7–3.8)	1.1 (0.8–1.5)	1.6 (1.1–2.2)
PSM									
	60–79	1.3 (1.1–1.6)	1.3 (0.9–1.8)	1.6 (1.2–2.2)	2.7 (1.8–4.3)	1.7 (1.2–2.2)	1.0 (0.8–1.3)	0.8 (0.6–1.3)	1.3 (1.1–1.6)
	40–59	1.7 (1.4–2.1)	1.4 (1.0–1.9)	2.0 (1.5–2.7)	2.2 (1.5–3.2)	1.5 (1.1–1.9)	1.6 (1.1–2.2)	1.1 (0.8–1.7)	1.6 (1.2–2.2)
	20–39	1.9 (1.4–2.4)	1.3 (1.0–1.8)	2.0 (1.5–2.5)	2.9 (1.9–4.2)	1.6 (1.2–2.2)	1.3 (0.8–2.0)	0.8 (0.6–1.1)	1.2 (0.9–1.6)

Multivariate models were produced using cumulative logistic regression for adults aged 20–79 years; independent reference groups were females, non-Hispanic whites, persons with at least some college experience, non-smokers, and individuals having had a dental visit in the past 12 months.
ALEI, attachment loss extent index; AL, attachment loss; dCPI, derived community periodontal index; PSM, periodontal status measure; OR, odds ratio; CI, confidence interval.

cal approach used age as a covariate and smoking as an effect modifier because smoking is an important exposure of interest that is susceptible to intervention-related activities.

The effects of smoking on periodontal status have been well established (Locker 1992, Haber et al. 1993, Johnson & Bain 2000, Tomar & Asma 2000). It has been suggested that continuous smoking compromises periodontal health and that over time, smoking cessation may produce an improved periodontal status comparable with that of non-smokers (Bergstrom et al. 2000). Our findings indicate that the effects of smoking on age differ by the type of periodontal measure selected. The odds of increasing periodontal disease status across all age groups for former smokers are similar to non-smokers when PSM is used. However, the relationship between smoking cessation and periodontal status becomes more complex when the other indices are used to assess increasingly poor periodontal health. For instance, the odds of increasing periodontal disease status as measured by dCPI are significant for former smokers only among those aged 60–79 years. When ALEI or AL is used, former smoking is significant only in the younger age groups.

We found low educational attainment (not completing high school) to be the only covariate to have consistent effects on the outcome variables across all strata. However, the effects of race/ethnicity across the age strata were more varied. The odds of increasingly poor periodontal disease status were more likely to be greater among non-Hispanic blacks when probing depth was used as a component of a periodontal measure (dCPI). Generally, Mexican American ethnicity was not associated with periodontal status regardless of the index used. Research findings consistently have indicated that non-Hispanic blacks experience greater prevalence and severity of periodontal disease in the US compared with other racial/ethnic groups. It recently has been suggested that demographic factors may have a greater influence on disease severity in non-Hispanic blacks compared with Asian Americans or Hispanics (Craig et al. 2001). Our findings indicate that there is no association between race/ethnicity and increasing periodontal disease status among those 60–79 years of age when ALEI or AL is

used to assess disease status but an association does exist when dCPI or PSM is used in the same age group.

Our findings support the notion that results from periodontal research activities may be influenced by information bias. Last describes this bias as ''a flaw in measuring exposure or outcome data that results in different quality of information between comparison groups'' (Last 1985). This concept may hold particular importance when researchers and evaluators are considering their research aims. Research goals and analytical plans need to account for limitations incurred by a specific periodontal measure; investigators should choose outcome measures for periodontal disease appropriate to the specific objectives of the study. For instance, if the research aim is to assess the influence of an intervention activity on reducing periodontal disease by utilizing mechanisms that increases the number of dental visits among a population at risk for disease, then a better primary outcome measure may be an index employing probing depth measures (such as dCPI or possibly PSM) with ALEI or AL as a less favorable choice. Our findings suggest that a CPI-similar index may be a better outcome variable to assess intervention effects at promoting dental utilization because with dCPI dental visits were associated with increasing periodontal disease status across all age strata, whereas with ALEI and AL they were not. Although CPI has been promoted as an effective tool for health services planning (Cutress et al. 1987), the index has rarely been used for that purpose (Baelum & Papapanou 1996).

We used four periodontal summary measures for this analysis (Table 1). They were chosen to provide a broad representation of methods used to measure periodontal status. All four measures used an ordinal scale to examine intensity of periodontal destruction in the study population. The ALEI measures the extent of clinical AL across all available probing sites and the AL measures the severity of clinical AL. For this analysis, we used the CPI (dCPI) modified from the WHO version to accommodate the probing sites used in NHANES III. In this analysis, we introduced a measure (PSM) that reflects the growing trend to report periodontitis as a composite assessment utilizing both probing depth and clinical AL information.

The structure of these four measures also represents differing processes in the use of periodontal data to describe the periodontal condition. The first process involves the aggregation of data. The dCPI and PSM identify the worst periodontal site assessed to derive a subject level score whereas ALEI and AL identify a summary measure representing a proportion of all sites. Another process involves the combination of information detailing various conditions of the periodontium such as bleeding or clinical AL. The presence of bleeding contributes information only to the dCPI and PSM indices whereas clinical AL is incorporated into three of the four indices. Consequently, these four measures present a broad yet contrasting picture of a population's periodontal status.

Among the measures used, we chose ALEI to be the standard for comparison purposes because it has been reported that a similar measure produces ''useful summary information'' in populations (Burt & Eklund 1999). When we compare the dCPI, PSM, and AL results from the ALEI cross-tabulations (Table 4), the distribution of the scores is similar across the ALEI categories. The majority of individuals who scored a 4 in dCPI, PSM, or AL had severe clinical AL extent (75+% ranges). When the periodontal scores 0, 1, and 2 were combined into one category (negative) as well as the scores of 3 and 4 (positive) into another category, and then compared with ALEI as the standard for advanced disease (scores 3 and 4) *versus* the alternative (scores 0, 1 and 2) the positive predictive value was 51%, 80%, and 99% for dCPI, PSM, and AL, respectively (data not shown). Conversely, the negative predictive value for dCPI, PSM, and AL was 80%, 82%, and 79%, respectively (data not shown). If loss of attachment extent is considered to be the standard to measure periodontal diseases in a population, a measure combining probing depth and clinical AL severity would be more appropriate to screen an entire population compared with CPI.

It has been reported that CPI (CPITN) underestimates the prevalence and severity of clinical AL in older age groups and overestimates these parameters in younger groups (Aucott & Ashley 1986, Baelum et al. 1995). Our analysis indicates that CPI (dCPI) may overestimate the prevalence of little to no clinical AL and may consistently underestimate increasingly more severe levels of clinical AL extent (Fig. 1). Clinical AL is a cumulative measure of disease and older age is directly associated with increasing prevalence. As mean clinical AL extent increases so should the numbers of older individuals affected. Thus, our observations correlate well with the findings from Baelum and coworkers that CPI underestimates prevalence of clinical AL in older populations. Our analysis also indicates that clinical AL scores of 0 and 4 may more closely approximate the prevalence of clinical AL extent but may significantly overestimate mean extent of clinical AL in the middle range of the scale (1,2, and 3). However, in this mid-range of the 0–4 scale, the PSM may better approximate mean extent of clinical AL compared with AL or CPI.

Given that clinical AL and probing depth measures are still ''practical and valid methods for assessing periodontal status'' (Armitage 2003), we used the CPI construct as an example of a measure that limits the inclusion of probed periodontal information to only probing depth measurements. Other studies have been presented comparing PI systems (Fleiss et al. 1987, Almas et al. 1991, Baelum et al. 1993, Diamanti-Kipioti et al. 1993) to existing periodontal conditions under a variety of methodological applications, including partial mouth exams. A recent study examined the relationship between three methods of collecting CPI information: if all teeth were examined, if two random quadrants with two sites at each tooth were examined, and if the WHO ten index teeth were examined (Beneigeri et al. 2000). Although some minor differences were found between the three methods, the pattern of the distribution of the individual CPI categories among the three methods was similar. There have been no studies comparing different periodontal measures and the effects of socio-demographic and smoking influences within the same study population. However, differences in effects among some risk indicators for periodontal disease between two different measures of periodontal disease (clinical loss of attachment *versus* radiographic bone loss) using ordinal regression have been reported (Grossi et al. 1995).

One-half mouth examinations may underestimate periodontal disease sites, particularly the more severe conditions (Ainamo & Ainamo 1985, Kingman et al. 1988, Hunt & Fann 1991) and the relationship between a partial mouth ESI and a full-mouth ESI varies among age groups (Papapanou et al. 1993). Furthermore, it has been reported that partial mouth recordings not only

underestimate prevalence of early clinical AL in young adult groups (16–20 year olds), but also overestimate extent of clinical AL (Eaton et al. 2001). A limitation of our study was that the PI scores were derived from a partial mouth examination. Consequently, the direction of the bias produced from under reporting advanced periodontal pockets or clinical AL may have underestimated the magnitude of the severity of disease or need for treatment. However, our study does minimize misclassification errors because examiners did not ascertain individual index scores and comparisons made across indices were based on the same set of standardized data. Another strength of this study is its use of a large, nationally representative sample of adults to explore and control for multiple risk factors.

The use of CPI (CPITN) in the epidemiology of periodontal disease is controversial (Baelum & Papapanou 1996). Although the original intent of the CPITN was to assess for increasing periodontal treatment needs in a population, the evolution of CPI from CPITN has created confusion towards its use as a method to assess periodontal status. The need to produce accurate assessments of periodontal outcome measures in research, intervention, and surveillance activities is important as dental researchers and public health professionals attempt to reduce disease disparity. It has been said that a hallmark of a good index for measuring health status is its simplicity of use, rapid application in the field, clear criteria for use, reproducibility by multiple examiners, and accuracy in quantification of conditions (Horowitz 1978). Given the lack of universal support for CPI as well as other methodologies employed in periodontal epidemiology, the time may be right for a renewed debate leading to the development of appropriate measures for use in periodontal epidemiology.

The results from our study show that demographic and behavioural factors associated with periodontal disease influences periodontal measures differently. These observations are important considerations as periodontal research broadens into biomedical research focusing on systemic associations and therapeutic or program evaluation. Our findings indicate that research and evaluation goals should account for the strengths and limitations of specific periodontal measures to improve outcome validity. Moreover, our findings suggest that substantial research in periodontal methodology should be undertaken to aid in the establishment of index and outcome measure standards for various research activities, including clinical research and program evaluation.

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