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Effect of partial recording protocols on severity estimates of periodontal disease

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Abstract

Objectives: The study aim was to assess bias magnitudes of periodontal disease severity estimates for specific partial recording protocols (PRPs) in epidemiological studies.

Material and Methods: Estimates of mean clinical attachment loss (MCAL) and mean probing pocket depth (MPPD) were derived for 20 different PRPs using full-mouth periodontal data from 1437 dentate Brazilian subjects 14–103 years old having at least four teeth. Biases, relative biases and intra-class correlations for all PRPs were evaluated. Graphical methods were used to assess how well the PRP-based estimates agreed with full-mouth scores across levels of disease.

Results: Slightly higher levels of disease were evidenced on lingual than on buccal sites. Seven multi-site PRPs and the Ramfjörd PRP produced small biases in MPPD (-0.17 to 0.04 mm) and MCAL with relative biases under 8% and 4% in absolute value for MPPD and MCAL, respectively. Biases for full- and random half-mouth-based PRPs were similar. The three-site random half-mouth MB–B–DL and the Ramfjörd PRPs produced the smallest biases, with relative biases $<3\%$ in absolute value for MPPD and MCAL.

Conclusions: Bias for MPPD or MCAL estimates varies by site type, number of sites per tooth and number of quadrants included in the PRP.

Key words: bias; mean periodontal probing pockets and attachment level; partial recording; periodontal diseases/diagnosis

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Currently the standard method for assessing periodontal disease in clinical research and periodontal practice involves a full-mouth clinical examination conducted on six sites per tooth. In large surveys and epidemiological studies of periodontal disease it is often not feasible to conduct the traditional full-mouth examination because it is time and labour intensive. The examination process could trigger patient and/or examiner fatigue, and would likely result in large measurement errors and large drop-out rates. Consequently investigators use a partial recording protocol (PRP) involving the examination of a subset of intra-oral sites. Specific PRPs have been reported and used in epidemiological studies of periodontal disease (Russell 1956, Ramfjörd 1959, Ainamo et al. 1982, Ainamo & Ainamo 1985, Carlos et al. 1986, Hunt et al. 1990, Papapanou et al. 1993, Brown et al. 1996, Albandar et al. 1999, Owens et al. 2003, Beck et al. 2006). These PRPs have ranged from a selection of a fixed set of teeth/sites (Ramfjörd 1959, Ainamo & Ainamo 1985) to a simple random sampling of sites per person (Beck et al. 2006). Hybrid PRP methods involving random sampling of clusters (quadrants) of teeth and fixed sites per selected tooth have been proposed. Specific random half-mouth PRP method have been used in large oral health surveys in the United States due to its simplicity, ease of use and brevity (Miller et al. 1987). The random half-mouth PRPs used in the US national surveys involve the random sampling of one maxillary quadrant and one mandibular quadrant followed by the examination of

Conflict of interest and source of funding statement

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a fixed set of sites on all teeth in the selected quadrants. Although partial recording methods underestimate the prevalence of periodontal disease, there is considerable variation in the degree of underestimation among PRPs (Susin et al. 2005). In addition, PRPs (specific subsets of sites per tooth) based on a full-mouth examination have also been used.

Kingman & Albandar (2002) studied the effect of selected PRPs on the estimates of periodontal disease prevalence in a sample of young subjects diagnosed with early-onset forms of periodontal disease including aggressive and chronic periodontitis, and a group of matched controls selected from a NIDR National Children's Survey. Findings from this study showed that estimates based on random half-mouth PRPs using two (MB–B) or three (MB–B–DB) sites significantly underestimated the prevalence of periodontal attachment loss $\geqslant 3$ mm and probing depth $\geqslant 4$ mm and produced substantial numbers of false negatives. Disease misclassification hinders or masks possible associations of periodontal disease with other conditions, by attenuating the corresponding measures of associations towards the null. In this study population PRPs based on three sites; one mid-tooth and two inter-proximal sites provided better estimates of the prevalence of periodontal probing pocket depth (PPD) and clinical attachment loss (CAL) than the combination of one inter-proximal and one mid-tooth site PRP. Because any PRP has a specificity of 1.0 (100%) when estimating prevalence of disease, the choice of a good PRP can be restricted to a comparison of its sensitivity. Among the three-site class of PRPs investigated, the MB–B–DB (NHANES IV) and the MB–B–DL combination (Fox 1991) had higher sensitivities for disease prevalence than the two-site PRP MB–B (NHANES III), regardless of cut-off value used to define disease (Kingman & Albandar 2002). This is a direct consequence of their hierarchical nature, i.e. augmenting the two-site NHANES III PRP (MB–B sites) by the addition of one proximal site per tooth (the DB site for NHANES IV PRP or the DL site in the MB–B–DL PRP suggested by Fox).

The effect of using a PRP to estimate disease severity can be more complex depending on the measure for disease severity. In this study we focused on the effects of using a random half- or full-mouth PRP to estimate mean probing pocket depth (MPPD) and mean clinical attachment loss (MCAL). The fixed set of Ramfjörd teeth was also included among the full-mouth-based PRPs for comparison purposes because historically it has been used estimate disease severity. The CPITN Index teeth (Ainamo & Ainamo 1985) and the simple random sampling methods (Beck et al. 2006) were not included in this study.

The optimal choice of PRP to adopt for a large-scale epidemiologic study such as a national survey should involve an appropriate balance between its effect on estimates of prevalence and extent or severity of periodontal disease. Ideally, one would like to select a PRP that produces reasonably high sensitivity for estimating disease prevalence and small biases for estimating disease severity. In this study we focus on the degree of bias in estimating periodontal disease severity.

Material and Methods

We used a representative sample of subjects 14–103 years old [mean: 35.3, standard deviation (SD): 15.5 years] living in 14 major municipalities that constitute the metropolitan area of Porto Alegre in the Brazilian state of Rio Grande do Sul. This sample consisted of 1586 persons who had a clinical dental examination. Of these 1465 (92.4%) were dentate subjects. A detailed description of the sampling method and the target population is provided elsewhere (Susin et al. 2004). We previously reported the effect of using PRPs on prevalence estimates of CAL in this population (Susin et al. 2005).

The subjects were examined clinically in a mobile examination centre consisting of a trailer equipped with a complete dental unit, and the centre was moved from one examination location to the next according to the survey schedule. Four dentists and two dental assistants conducted the fieldwork. All permanent fully erupted teeth, excluding third molars, were examined with a manual periodontal probe (PCP10-SE, Hu-Friedy Mfg. Co. Inc., Chicago, IL, USA) colour coded at 1, 2, 3, 5, 7, 8, 9 and 10 mm. Six sites per tooth were assessed in the mesiobuccal (MB), midbuccal (B), distobuccal (DB), distolingual (DL), midlingual (L), and mesiolingual (ML) sites.

Probing depth was defined as the distance from the free gingival margin to the bottom of the pocket/sulcus. Gingival recession was defined as the distance from the cementoenamel junction (CEJ) to the free gingival margin, and this assessment was assigned a negative sign if the gingival margin was located coronal to the CEJ. Periodontal attachment loss was defined as the distance from the CEJ to the bottom of the pocket/sulcus, and was calculated as the sum of the probing depth and gingival recession measurements. Measurements were made in millimetres and were rounded to the lower whole millimetre.

PRPs

Overall, we evaluated a total of 20 PRPs:

- Twelve one-site PRPs: six random half-mouth PRPs and six full-mouth PRPs. The single sites were MB, B, DB, ML, L and DL
- Two two-site PRPs: one random half-mouth PRP (as in NHANES III) and one full-mouth PRP. The two sites were MB–B.
- Four three-site PRPs: two random half-mouth PRPs and two full-mouth PRPs. The two combinations of three sites were MB–B–DB (as in NHANES IV) and MB–B–DL.
- One random half-mouth six-site PRP. The six sites were MB–D–DB–ML–L–DL.
- One six-site PRP using the Ramfjörd teeth. The six sites were MB–D–DB–ML–L–DL.

Because they have been used in the past or because they may have particular appeal for future surveys, we focused on eight PRPs:

Half-mouth PRPs:

(a) MB–B measurements (also labelled as NHANES III)
(b) MB–B–DB measurements (also labelled as NHANES IV)
(c) MB–B–DL measurements
(d) MB–B–DB–ML–L–DL measurements (also termed six-site PRPs).

Full-mouth PRPs:

(e) MB–B measurements
(f) MB–B–DB measurements
(g) MB–B–DL measurements
(h) MB–B–DB–ML–L–DL measurements on six ''Ramfjörd'' teeth – right maxillary first molar, left maxillary central incisor, left maxillary first premolar, left mandibular first molar, right mandibular central incisor and right mandibular

first premolar. MPPD, recession and CAL were computed using all six sites per tooth for the six Ramfjörd teeth, based on a maximum of 36 possible sites per mouth. No replacements for missing Ramfjörd teeth were made.

Data analysis

Five of the 1465 dentate subjects were excluded due to health-related conditions. Twenty-two subjects had one to three teeth and one subject had five teeth, but all in one quadrant. Consequently several PRPs had missing values for these subjects and they were also excluded. The results presented here are based on the remaining 1437 study subjects. MPPD and MCAL were derived for all study subjects. There were 1430 study subjects who had at least one Ramfjörd tooth, and the associated analyses for the Ramfjörd PRPs are based on these 1430 subjects.

Bias was defined as the difference between the computed PRP and the full-mouth [FM (true)] score for each PRP separately for MPPD and MCAL, i.e.

$$\text{bias (PRP)} = \text{PRP (mean)} - \text{FM (true)}$$

Bias was estimated for each PRP, separately, together with their standard error. For each PRP the relative bias was calculated as 100 times the respective bias divided by the full-mouth subject mean score, i.e.

$$\text{relative bias (PRP)} = 100 \times \text{bias (PRP)}/\text{FM (true)}$$

Paired *t*-tests were performed on the differences between a PRP mean and the full-mouth mean within subjects to investigate statistical significance of the biases for the half- and full-mouth PRP for MPPD and MCAL, respectively.

Intra-class correlation analyses were conducted separately for each PRP based on the linear mixed model

$$y_{ij} = \mu + s_i + P_j + \varepsilon_{ij}$$

where y_{ij} represents the mean score for the ith subject using the jth PRP, s_i an effect for the subject, P_j the effect of the PRP and e_{ij} the measurement error. Here $i = 1$ to N (number of subjects), $j = 1, 2$ ($M = 2$ = number of subject scores). We assumed subjects and measurement error to be random effects while the PRP effect was considered as a fixed effect.

For a specific PRP the intra-class correlation coefficient can be defined as

$$\rho = \frac{\sigma_S^2}{(\sigma_S^2 + \theta_P^2 + \sigma_e^2)}$$

Here σ_S^2 and σ_e^2 represent the variances due to subjects and measurement error, respectively, and

$$\theta_P^2 = \frac{1}{(M-1)} \sum P_j^2$$

where P_j is the effect associated with the jth level of PRP (specific PRP *versus* FM), respectively. The ICC estimate is given as

$$\text{ICC} = \frac{N(\text{MSS} - \text{MSE})}{N \times \text{MSS} + M \times \text{MSP} + (N \times M - M - N)\text{MSE}}$$

Here MSS, MSP and MSE are the mean square errors associated with subjects, $N = 1437$, $M = 2$ (for Ramfjörd PRP, $N = 1430$, $M = 2$). Large values for the ICC indicate high agreement between the specific PRP and the FM mean scores. The 95% confidence limits for the corresponding ICC estimates are derived using the method presented by McGraw & Wong (1996).

Bland–Altman plots (Bland & Altman 1986), plots of the differences between the PRP and full-mouth mean scores against their average score, are used to investigate and assess the agreement pattern within patients across the disease spectrum for each multi-site PRP separately.

The statistical analyses were performed for the 1437 subjects (1430 for Ramfjörd) in the study population using SAS 9.1® (SAS Institute 2004).

Measurement reproducibility

At two time points, before and 3 months after the start of the study, the examiners were trained and calibrated in performing the clinical measurements. The examination team followed a quality control protocol aimed at reducing systematic and random measurement errors and to quantify what error remained. The protocol involved standard examination environment and methodology, standard equipment and detailed written instructions for clinical procedures. Further details are reported elsewhere (Susin et al. 2005).

Results

The four field examiners showed high reliability for MPPD and MCAL. The intra-examiner reliability estimates for the gold standard examiner (ICC ⩾ 0.98). High inter-examiner reliability estimates for these measures were observed (ICC ⩾ 0.88). Examiner bias was minimal, < 3% for MCAL and 4% for MPPD. The lower limits of the associated 95% CI's were all > 0.75.

The age distribution of the study population is illustrated in Fig. 1. The mean age was 35.3 years (SD = 15.5). About 55% were 35 years or younger, 34% were 36–55 and 11% were 56 and older. Other demographics for the study population are included in Table 1.

The distribution of permanent teeth and number of randomly selected teeth are illustrated in Fig. 2a and b, respectively. Full-mouth PRPs for the 1437 study subjects are based on an average of 22.0 teeth and 11.0 teeth for the random half-mouth PRPs. Thus, on average, one needs to evaluate 33 sites per subject for the three-site MB–B–DL or MB–B–DB PRPs. There are 4.5 Ramfjörd teeth per subject, which requires, on average, an evaluation of 27 sites per subject.

A summary for the MCAL estimates for each PRP is presented in Table 2. The true full-mouth MCAL was 1.56 mm for this study population. The MCAL results for the four half-mouth PRPs and four full-mouth PRPs are highlighted. Biases for the multi-site PRPs MCAL estimates are all < 0.1 mm and the associated relative biases range between − 4.6% and 0.9%. MCAL biases (relative biases) for the NHANES III and NHANES IV half-mouth PRP were − 0.04 mm (− 2.3%) and − 0.05 mm (− 3.4%); their corresponding full-mouth versions were − 0.05 mm (− 3.5%) and − 0.07 mm (− 4.6%). The smallest bias observed 0.01 mm (0.4%) was for the half-mouth MB–B–DL PRP estimate and the bias for its corresponding full-mouth estimate was − 0.01 mm (− 0.8%).

The MCAL estimate based on the Ramfjörd PRP has a 0.04 mm (2.8%) positive bias.

The biases for the single-site PRPs MCAL estimates are also presented in Table 2 to facilitate the interpretation of the results. MCAL estimates are larger for the lingual sites than for buccal sites. The biases (relative biases) for the single-site PRPs estimates were more

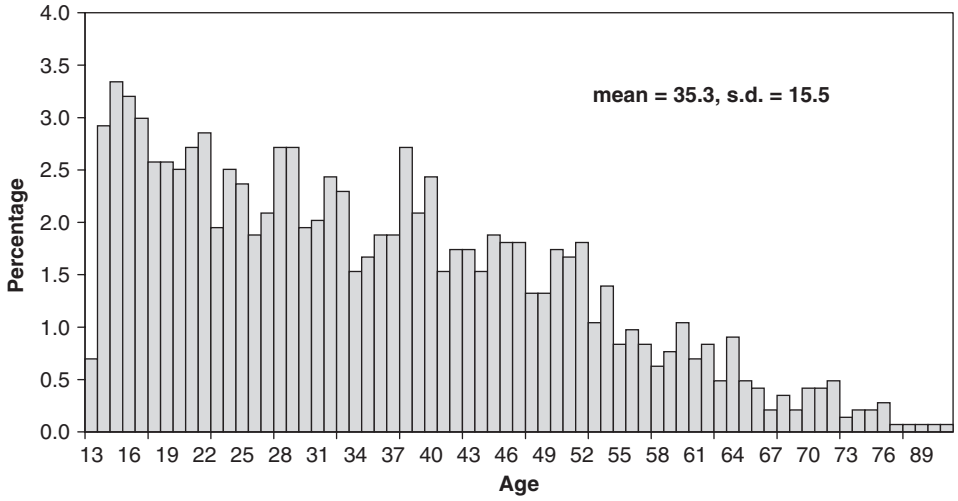

Fig. 1. Age distribution of study cohort.

Table 1. Characteristics of the Brazilian sample

Characteristic	Number	%
Clinically examined	1586	–
Edentulous	121	7.6
Having 1–3 teeth*	23	1.5
Missing data	5	0.3
Study population	1437	100.0
Gender		
Male	667	46.4
Female	770	53.6
Socioeconomic		
Low	509	35.4
Moderate	420	29.2
High	508	35.4
Ethnicity		
White	1169	81.4
Non-white	268	18.6
Education		
None	38	2.6
1–4	215	15.0
5–8	593	41.3
Some HS	220	15.3
HS grad	246	17.1
Some college	69	4.8
College grad	56	3.9
Smoking		
Never	806	56.1
Current/previous	631	43.9

*Includes one subject with five teeth in one quadrant.

variable, averaging between -0.17 mm (-11.0%) and 0.14 mm (9.2%). There are no statistically significant biases for the eight primary PRPs investigated in estimating MCAL. Any PRP whose relative bias exceeded 6% for estimating MCAL is statistically significant.

The agreement patterns in MCAL scores for study subjects are presented using Bland–Altman plots in Fig. 3 for the half-mouth versions of NHANES III, NHANES IV, MB–B–DL and six-site PRPs. The SDs for the MCAL scores are slightly larger than the associated means (coefficients of variation varied from 1.10 to 1.13). Negligible negative trends among MCAL differences for subjects are evident across disease severity. Larger variations among subject-specific MCAL differences are evidenced for the half-mouth NHANES III and NHANES IV PRPs compared with those for the MB–B–DL or the six-site half-mouth PRPs.

A summary for the MPPD estimates for each PRP is presented in Table 3. The true full-mouth MPPD is 2.32 mm for this study population. The biases for MPPD for the multi-site PRPs are all <0.2 mm in absolute value but more varied than those for MCAL. The associated relative biases range from -7.4% to 0.1%. The bias (relative bias) for the NHANES III and NHANES IV half-mouth PRP MPPD estimates are -0.17 mm (-7.2%) and -0.11 mm (-4.8%) and similar to their full-mouth versions [-0.17 mm (-7.4%) and -0.11 mm (-4.9%)], respectively. The bias and relative biases for the MB–B–DL PRP-based MPPD are much smaller, -0.03 mm (-1.3%) for both the half-mouth and full-mouth version.

The MPPD estimate based on the Ramfjörd PRP has a -0.04 mm (-1.9%) negative bias.

The results for the single-site PRPs for MPPD are also presented in Table 3. The biases for single-site PRPs for MPPD average around 0.20 mm, with much more variation by site type, ranging from -0.40 mm (-17.3%) for mid-buccal sites to 0.25 mm (11.5%) for the distolingual sites. Generally the lingual-based MPPD scores are greater than the buccal-based MPPD scores. The half- and full-mouth versions of a PRP produce similar biases for MPPD. Any PRP whose relative bias exceeded 1% for estimating MPPD is statistically significant.

Bland–Altman plots displaying the agreement patterns in MPPD differences for study subjects are given in Fig. 4 for the NHANES III, NHANES IV, MB–B–DL and six-site half-mouth PRPs. The SDs for MPPD scores are much smaller than their associated means (coefficients of variation varied from 0.22 to 0.24). The variation among subject differences is more evident for the NHANES III and NHANES IV random half-mouth PRPs than for either the MB–B–DL or the six-site half-mouth PRPs.

ICCs for PRP agreement with the FM scores are presented in Table 4, together with the associated 95% confidence intervals (CIs). The ICCs ranged between 0.96 and 1.00 for assessing attachment loss and between 0.84 and 0.98 for PPD. Agreement levels for attachment loss tended to be larger than those for PPD. The lower limits for all 95% CIs were >0.80, except for the NHANES III random half-mouth or full-mouth PRP in assessing MPPD.

Discussion

Knowledge of the level of underestimation in periodontal disease prevalence and potential bias in estimation of disease severity by using PRPs has become

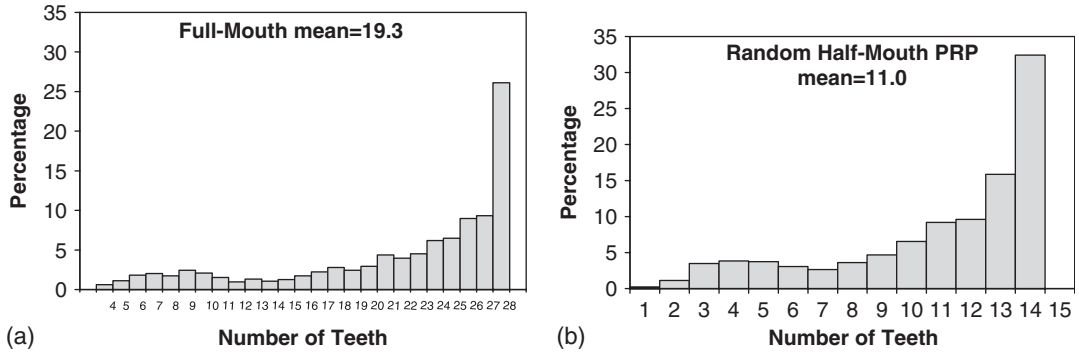

Fig. 2. Distribution of numbers of teeth for full- and random half-mouth.

Table 2. Bias and relative bias for attachment loss

Outcome	*N*	Mean	SD	Bias*	Relative bias (%)	*P*-value
Half-mouth PRPs						
MB	1437	1.41	1.77	−0.15	−9.6	0.001
B	1437	1.64	1.73	0.08	4.9	0.097
DB	1437	1.47	1.72	−0.09	−5.5	0.061
ML	1437	1.57	1.95	0.01	0.7	0.833
L	1437	1.70	1.95	0.14	9.2	0.005
DL	1437	1.65	2.00	0.09	5.8	0.086
NHANES III	1437	1.52	1.72	−0.04	−2.3	0.422
NHANES IV	1437	1.51	1.71	−0.05	−3.4	0.242
MB–B–DL	1437	1.56	1.77	0.01	0.4	0.905
6 Sites	1437	1.57	1.79	0.01	0.9	0.766
Full-mouth PRPs						
MB	1437	1.39	1.68	−0.17	−11.0	<0.001
B	1437	1.62	1.66	0.06	4.0	0.149
DB	1437	1.45	1.64	−0.11	−6.8	0.014
ML	1437	1.57	1.88	0.01	0.4	0.896
L	1437	1.70	1.91	0.14	8.9	0.006
DL	1437	1.63	1.92	0.07	4.5	0.167
NHANES III	1437	1.51	1.65	−0.05	−3.5	0.217
NHANES IV	1437	1.49	1.64	−0.07	−4.6	0.099
MB–B–DL	1437	1.55	1.71	−0.01	−0.8	0.779
Ramfjörd	1430	1.60	1.81	0.04	2.8	0.358

*These are differences from the 1.56 mm true full-mouth MCAL value.
SD, standard deviation; MB, mesiobuccal; B, midbuccal; DB, distobuccal; DL, distolingual; L, midlingual; ML, mesiolingual; PRP, partial recording protocol.

a key concern in dental research. This is particularly important for two reasons. Firstly, assessments of periodontal disease in most large national surveys are based on PRPs, necessitated by time and logistical constraints. We have previously shown (Kingman et al. 1988, Susin et al. 2005) PRPs systematically produces underestimates of periodontal disease prevalence. In this study, we show that these specific PRPs have much less impact on estimates of disease severity, given that one defines severity of disease by the MCAL or MPPD. We did not investigate what impact they have on other measures of disease severity such as those discussed by Diamanti-Kipioti et al. (1993).

Secondly, many recent reports have been published suggesting an association between periodontal disease and other medical conditions, including cardiovascular disease, pre-term and low birth weight, pulmonary disease and even diabetes. Some of these reports are based on PRP prevalence estimates of periodontal disease and, therefore, are susceptible to substantial bias and misclassification of risk. The effect of misclassification is the attenuation in magnitude of estimated correlation coefficients in association studies. Thus a real correlation between periodontal disease and any of these systemic diseases/conditions could go undetected due to the use of a PRP. Consequently it is important to document what potential biases for disease prevalence and/or severity may exist due to the use of these PRPs.

One of the primary strengths of this study is access to full-mouth periodontal assessments from a large sample of a Brazilian population who has large variation in periodontal disease severity. These data provide us with a unique opportunity to investigate the effects of specific PRPs in estimating disease prevalence or disease severity with relatively high precision. The distribution of attachment loss is readily evident, with more disease evidenced on lingual than buccal sites, separately for each of the three probing sites. The mid-tooth sites have the most severe attachment loss and the smallest level of pocketing, reflecting the higher levels of recession of the mid-tooth sites. Positive MCAL biases were realized for the half- and full-mouth B, ML, L and DL single-site PRPs and negative for the MB and DB single-site PRPs. PPD was more severe for proximal sites, especially for the ML and DL sites.

The biases associated with the half-mouth PRPs investigated here illustrates that the level of bias incurred for estimating the MCAL or MPPD is small, $<7.5\%$ for MPPD and $<5\%$ for MCAL. The only PRPs that produced relative biases $>5\%$ were the half- and full-mouth NHANES III PRPs for MPPD. Two particular PRPs, the 42-site-based half-mouth MB–B–ML and the Ramfjörd, performed very well, having biases (under 2%) for estimating disease severity. Although we did not include the Ramfjörd PRP in our previous report (Susin et al. 2005), the random half-mouth MB–B–DL PRP performed much better in this study population for estimating prevalence of CAL and PPD for almost all cut-off values defining disease than did the Ramfjörd PRP.

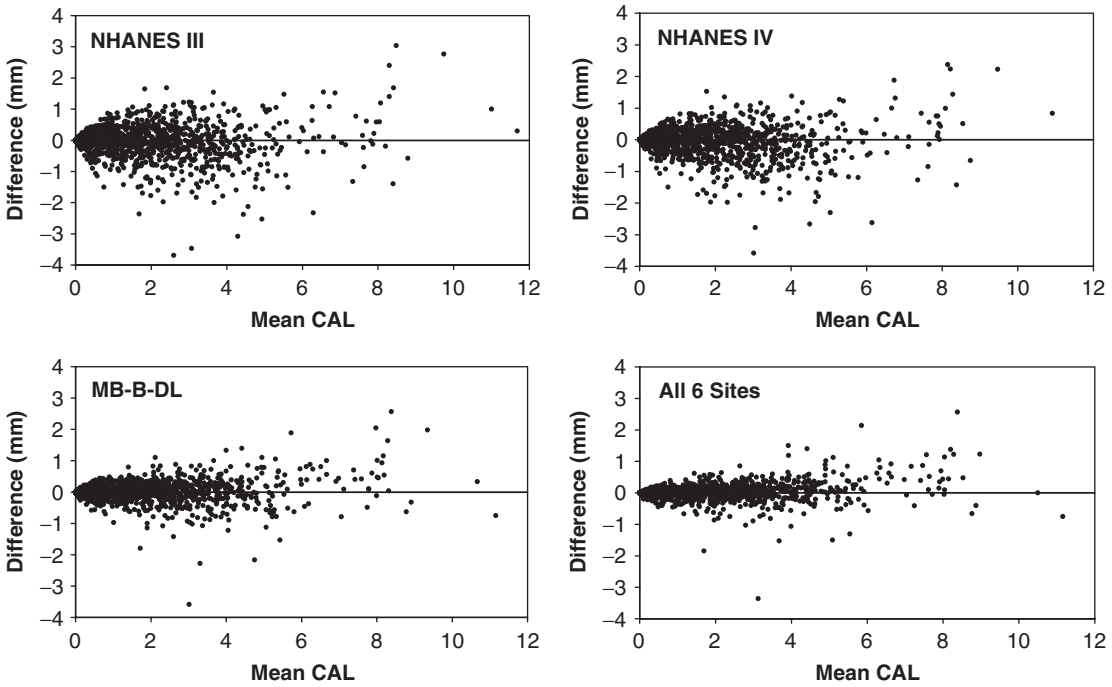

Fig. 3. Differences *versus* averages in clinical attachment loss means for random half-mouth partial recording protocols.

Table 3. Bias and relative bias for probing pocket depth

Outcome	*N*	Mean	SD	Bias*	Relative bias (%)	*P*-value
Half-mouth PRPs						
MB	1437	2.39	0.58	0.07	2.9	<0.001
B	1437	1.92	0.52	−0.40	−17.3	<0.001
DB	1437	2.33	0.61	0.01	0.2	0.733
ML	1437	2.59	0.70	0.26	11.3	<0.001
L	1437	2.15	0.67	−0.17	−7.4	<0.001
DL	1437	2.57	0.73	0.25	10.7	<0.001
NHANES III	1437	2.16	0.52	−0.17	−7.2	<0.001
NHANES IV	1437	2.21	0.53	−0.11	−4.8	<0.001
MB–B–DL	1437	2.29	0.55	−0.03	−1.3	0.044
6 Sites	1437	2.33	0.57	0.00	0.1	0.931
Full-mouth PRPs						
MB	1437	2.38	0.52	0.06	2.5	<0.001
B	1437	1.92	0.49	−0.40	−17.2	<0.001
DB	1437	2.33	0.56	0.00	0.1	0.887
ML	1437	2.59	0.67	0.27	11.5	<0.001
L	1437	2.15	0.65	−0.18	−7.6	<0.001
DL	1437	2.57	0.69	0.25	10.8	<0.001
NHANES III	1437	2.15	0.48	−0.17	−7.4	<0.001
NHANES IV	1437	2.21	0.50	−0.11	−4.9	<0.001
MB–B–DL	1437	2.29	0.52	−0.03	−1.3	0.024
Ramfjörd	1430	2.28	0.58	−0.04	−1.7	0.003

*These are differences from the 2.32 mm true full-mouth MPPD value.
SD, standard deviation; MB, mesiobuccal; B, midbuccal; DB, distobuccal; DL, distolingual; L, midlingual; ML, mesiolingual; PRP, partial recording protocol.

These findings need to be cautiously interpreted when extrapolated to other populations. The possibility exists that the degree of bias may vary with the severity of disease in the population in addition the specific PRP that is used to report disease severity. There have been very few studies published having comparable data with which to make comparisons. Dowsett et al. (2002) reported similar findings for the six-site random half-mouth PRP in a Guatemalan population that had higher levels of disease (full-mouth MCAL = 1.76 mm and full-mouth MPPD = 2.88 mm). In a Tanzanian population, the Ramfjörd PRP was shown to have <1% relative bias for MPPD (Mumghamba et al. 2004).

The disease severity in this Brazilian study population was substantially higher than that reported for the comparably aged US population in either the NHANES III (CAL = 1.22 mm; PPD = 1.47 mm) or the NHANES IV 1999–2002 (CAL = 0.85 mm; PPD = 1.03 mm) surveys (National Center for Health Statistics Website 2007). However, even though we know the level of bias incurred by their use in our Brazilian study population, we would need to conduct extrapolations based on our findings to obtain realistic disease levels in the US population because we do not have direct evidence for the US surveys.

There have been reports of studies conducted in US populations for which full-mouth assessments are available. A study was conducted in a health maintenance organization for a managed care population (Stoltenberg et al. 1993) for which the investigators reported a full-mouth MPPD = 2.95 mm. No data were presented for attachment loss. Although they reported results for estimating prevalence of PPD with several PRPs, they did not report comparable results for PRP-based estimates of MPPD for disease severity.

For a case–control study conducted in a western New York State, population researchers (Andriankaja et al. 2006)

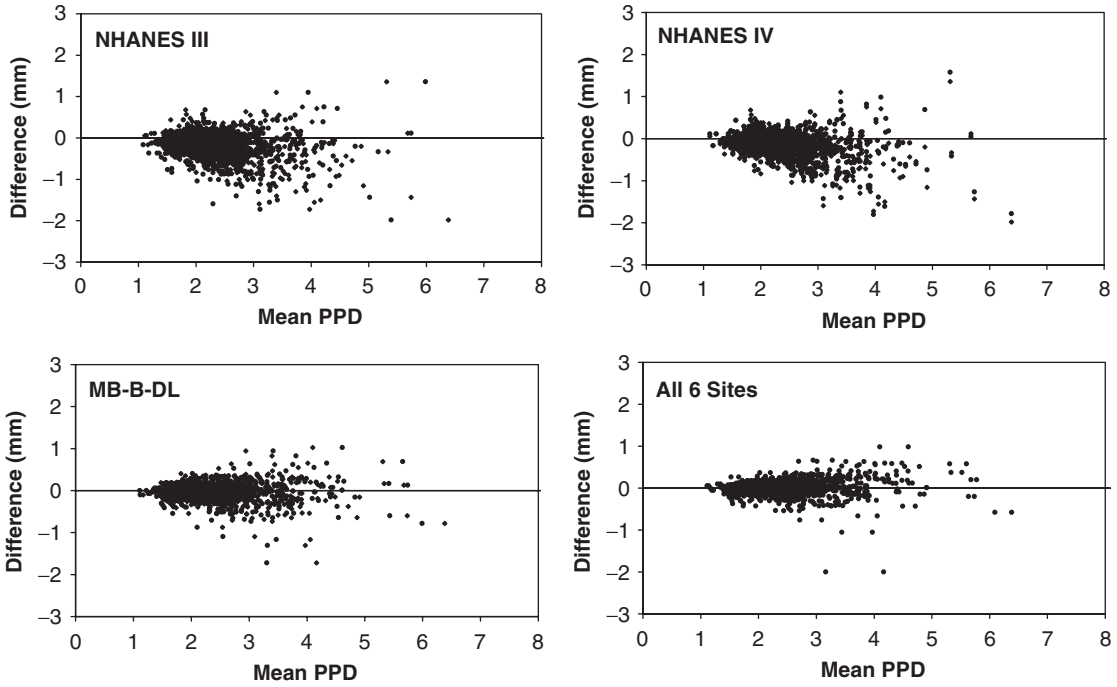

Fig. 4. Differences *versus* averages in probing pocket depth means for random half-mouth partial recording protocols.

Table 4. Summary of agreement measures for study population variance components and intra-class correlation coefficients

PRP	*N*	Var S^*	Var $T^\dagger$	Var *E*	ICC	95% CI	
						lower	upper
Attachment loss							
Half-mouth							
NHANES III	1437	2.85	0.00	0.14	0.91	0.90	0.92
NHANES IV	1437	2.85	0.00	0.11	0.93	0.92	0.93
MB–B–DL	1437	3.01	0.00	0.06	0.96	0.96	0.97
6 Sites	1437	3.06	0.00	0.04	0.98	0.97	0.98
Full-mouth							
NHANES III	1437	2.78	0.00	0.08	0.94	0.94	0.95
NHANES IV	1437	2.77	0.00	0.06	0.95	0.95	0.96
MB–B–DL	1437	2.94	0.00	0.01	0.99	0.99	0.99
Ramfjörd	1430	3.00	0.00	0.11	0.93	0.92	0.93
Probing pocket depth							
Half-mouth							
NHANES III	1437	0.25	0.01	0.03	0.76	0.74	0.78
NHANES IV	1437	0.26	0.01	0.03	0.80	0.78	0.82
MB–B–DL	1437	0.29	0.00	0.02	0.90	0.89	0.91
6 Sites	1437	0.30	0.00	0.01	0.94	0.93	0.94
Full-mouth							
NHANES III	1437	0.24	0.02	0.02	0.82	0.80	0.84
NHANES IV	1437	0.25	0.01	0.02	0.87	0.85	0.88
MB–B–DL	1437	0.28	0.00	0.00	0.97	0.97	0.97
Ramfjörd	1430	0.30	0.00	0.02	0.87	0.85	0.88

*Variance component due to subject differences.

†Estimated fixed effects parameter θ^2.

SD, standard deviation; MB, mesiobuccal; B, midbuccal; DL, distolingual; L, midlingual; PRP, partial recording protocol.

reported MCALs that were 50–100% higher than for our Brazilian population (full-mouth MCAL = 3.00 mm, MPPD = 2.30 mm). Beck reported full-mouth MCAL = 1.77 mm and MPPD = 1.89 mm (Beck et al. 2006) using data from the Dental Atherosclerosis Risk in Communities Study that was conducted in four US sites (Nakib et al. 2004). These investigators reported relative biases for MCAL using the NHANES III and NHANES IV PRPs similar to ours (<5%), but larger relative biases for MPPD. Their study population had higher disease severity levels than those reported in NHANES III or NHANES IV. Thus, considerable variation in disease severity is possible for subgroups within a population as well as between populations.

The NHANES IV national survey used a random half-mouth PRP involving three buccal sites per tooth (MB–B–DB). However, our results show a substantial reduction in bias for disease severity can be achieved by using the random half-mouth MB–B–DL PRP, requiring a mere substitution of the DL site for the DB site. We have previously reported that the half-mouth MB–B–DL PRP performed better for estimating the prevalence of disease as well (Susin et al. 2005). Fox reported similar findings for a New England population (Fox 1991).

The Ramfjörd teeth, originally selected as a representative of the full-mouth for estimating disease severity, performed very well for both MCAL (RB = 2.8%) and MPPD (RB = − 1.9%). This was also evidenced in a Tanzanian population (Mumghamba et al. 2004). However, as we reported earlier here, the Ramfjörd PRP produces larger biases for estimating both CAL and PPD than the random half-mouth MB–B–DL PRP. Fleiss et al. (1987) also

demonstrated that the Ramfjörd teeth severely underestimated prevalence of PPD in a veterans population. Therefore based on our findings for the performance of the random half-mouth MB–B–DL PRP in estimating disease prevalence and disease severity we would recommend the half-mouth MB–B–DL PRP be selected.

Differences in agreement for MCAL and MPPD scores for study subjects demonstrate that the MB–B–DL and Ramfjörd PRPs perform well across a wide range of the disease spectrum. NHANES IV PRPs performed acceptably, but not as well as the other two. The NHANES III PRPs faired much worse, especially for estimating MPPD. This is reflected as well in their smaller ICC values, particularly the lower bounds for their CIs.

Considered as a set of multi-site candidates, these PRPs performed much better for estimating MCAL and MPPD than for estimating prevalence of CAL or PPD (Susin et al. 2005). The relative biases for all multi-site PRPs were within 5% for this study population, except for the NHANES III PRPs MPPD estimates.

Our findings suggest that one may better reflect the severity of disease via the MCAL or MPPD than by the prevalence of disease using some fixed maximum cut-off value for CAL or PPD if only PRP-based clinical assessments are available. The MCAL or MPPD measures of disease are much less susceptible to misclassification than those based on some variation of the maximum attachment level or PPD measurement for the subject. This can be particularly important in studies investigating the association of periodontal disease with other clinical signs or diseases.

In large surveys, limited resources, including manpower, funds, multiple examiners and time, are among the main rationales for not using the traditional full-mouth examination of 168 sites. In addition, other fieldwork logistical constraints may influence the choice of the partial recording method. A careful consideration of these factors should be undertaken to select a suitable diagnostic method that shows satisfactory precision. In future, large surveys we would strongly suggest that full-mouth examinations on a random subset (5–10%, say) of sampled subjects be conducted to obtain direct evidence of the probable magnitude of bias incurred for the PRP that is used in the survey. Until such evidence is available more convenience-based databases will need to be investigated to determine the probable levels or bounds on the bias produced by the PRPs.

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Clinical Relevance

Scientific rationale for the study: Feasibility constraints necessitate the use of partial recording methods to obtain periodontal disease information in large studies. Documentation and validation of partial recording methods that produce estimates of disease prevalence and severity with minimal bias is important.

Principal findings: An examination of the MB, B, and DL sites for a random half-mouth produced estimates of periodontal disease severity with $<2\%$ relative bias.

Practical implications: Because the three sites per tooth (MB, B, DL) random half-mouth method had very small bias in estimating disease severity and also has demonstrated high sensitivity for estimating disease prevalence (previous report for this population), it may be an excellent choice for large-scale epidemiologic studies.