



ORIGINAL ARTICLE

Accuracy and precision of using partial-mouth recordings to study the prevalence, extent and risk associations of untreated periodontitis

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KEYWORDS

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Abstract *Objective:* To study the accuracy and precision of estimating the prevalence, extent and associated risks of untreated periodontitis using partial-mouth recording protocols (PRPs) **Methods:** A purposive sample of 431 individuals who had never been treated for periodontal disease was recruited from screening clinics at the King Saud bin Abdul-Aziz University for Health Sciences. Data were collected using questionnaires and clinical examinations. The prevalence, extent and risk associations of periodontitis were evaluated. Three PRPs were compared to full-mouth recordings (FRPs) in terms of the sensitivity, specificity, predictive values, and absolute bias. **Results:** The prevalence of periodontitis was estimated with the highest accuracy and precision by examinations of the full mouth at the mesiobuccal and distolingual sites (FM)MB-DL, followed by random half-mouth (RHM) recordings. The extent of periodontitis was estimated with high precision using all the PRPs, and the absolute bias ranged from -0.6 to -2.3 . The absolute bias indicated by OR for risk associations was small for the three PRPs and ranged from -0.8 to 0.8 .

Abbreviations: PPV, Positive Predictive Value; NPV, Negative Predictive value; (HM)MB-DL, Half-Mouth at Mesiobuccal and Distolingual; (FM)MB-DL, Full-mouth at Mesiobuccal and Distolingual; RHM, Random-Half-Mouth; PRP, Partial-mouth Recording Protocol; FRP, Full-mouth Recording Protocol; CAL, Clinical Attachment Loss; PPD, Periodontal Probing Depth; CDC, Centers of Disease Control and Prevention; AAP, American Academy of Periodontology; OR, Odds Ratio; LN, Natural Logarithm

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Conclusion: (FM)MB-DL and RHM were the PRPs with moderate to high levels of accuracy and precision for estimating the prevalence and risk associations of periodontitis. The extent of periodontitis was estimated with high precision using all three PRPs. The results of this study showed that the magnitude and direction of bias were associated with the severity of periodontitis, the selected PRPs and the magnitude of the risk associations.

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1. Introduction

The two main goals of epidemiological studies are to estimate the disease distribution and its risk associations (Lilienfeld D, 1978). The full-mouth periodontal recording protocol (FRP) at 28 teeth, with six sites per tooth, is considered the gold standard (Holtfreter et al., 2015). By comparison, the partial-mouth-recording protocol (PRP) is a more convenient and cost-effective approach for population-based studies. However, examining periodontitis using PRPs has generally resulted in a differential misclassification bias because findings can be biased either toward or away from the null hypothesis (Preisser et al., 2018).

More than 32 PRPs have been proposed in the literature and tested for their accuracy in estimating the prevalence, extent and severity of periodontitis (Tran et al., 2013). The most frequently used PRPs are Ramfjord teeth (Ramfjord P, 1959), a protocol developed by the third National Health And Nutrition Examination Survey (NHANES III) for the examination of mesiobuccal and midbuccal sites of the random half-mouth (RHM), the NHANES IV protocol for the examination of the mesiobuccal-midbuccal-distobuccal sites of the RHM, or RHM recordings using six sites per tooth. Factors that have been found to contribute to information loss when using PRPs include the population age, total number of remaining teeth, definition of periodontitis cases, and selection of the minimum number of teeth and sites (Heaton, Sharma, et al., 2018; Peres et al., 2012).

Most of the studies in which the accuracy of PRPs was assessed in comparison to FRPs mainly focused on studying the prevalence, extent and severity of periodontitis (Beck et al., 2006; Kingman A et al., 2008). Recently, the precision of PRPs in estimating the risk associations of periodontitis has also been assessed (Akinkugbe et al., 2015; Alshihayb et al., 2020). Factors that influenced the magnitude of the bias when using PRPs included the sensitivity of case definitions, extent and severity of periodontitis, and magnitude of specific risk associations (Heaton, Garcia, et al., 2018)

In early studies, the natural history of periodontitis was examined in untreated subjects using partial recordings at fixed sites for the whole mouth (Loe H et al., 1978; Timmerman M et al., 2000), but the corresponding accuracy was not evaluated. Only one previous study focused on the accuracy of using RHM and Ramfjord teeth to study the prevalence of untreated periodontitis and severity estimates (Dowsett et al., 2002a). Higher accuracy was found using RHM compared to the Ramfjord teeth protocol. However, the precision of using PRPs to estimate the risk associations in untreated subjects remains unknown.

The specific aims of this study were to determine the accuracy and precision of estimating the prevalence, extent and risk associations of untreated periodontitis using PRPs.

2. Materials and methods

2.1. Study subjects

The current study was based on a purposive sample of subjects who had never been treated for periodontal conditions that were recruited from the screening dental clinics at the College of Dentistry at King Saud bin Abdul-Aziz University for Health Science in Saudi Arabia. Most of the study subjects resided in rural areas surrounding Riyadh city and thus had limited access to dental care. The recruitment period ranged from September 2019 to the end of December 2019. Ethics approval was obtained from the King Abdullah International Medical Research Center (H-01-R-005). Consent forms were signed by all participants prior to data collection. Inclusion criteria: subjects who were dentate or partially dentate and had never been treated for periodontal conditions (the dental history was limited to emergency dental treatments), were able to communicate in Arabic or English, did not need premedication, and did not have cellulitis, acute dental abscesses, cysts, or tumors.

2.2. Data collection

Clinical examinations were performed by a certified periodontist using a FRP including 28 teeth, with six sites per tooth. Intraexaminer agreement was tested by employing duplicate measurements of 10 subjects using Cohen's kappa; two thresholds were used: clinical attachment loss (CAL) ≥ 3 mm at ≥ 2 interproximal sites and CAL ≥ 5 mm at ≥ 2 interproximal sites.

Questionnaires were used to collect background information, including sociodemographic data, medical conditions, use of medications, oral health-related behaviors, perceived stress¹ and perceived social support². Cohen's kappa test was used to determine the reliability of the subjects' responses by comparing the responses to a repeated question about education levels. The internal consistency of the subjects' answers to a 10-item perceived stress scale and a 12-item perceived social support were tested using Cronbach's alpha.

2.3. Study outcomes and selection of partial-mouth-recording protocols

The PRPs selected were as follows: 1) RHM at two diagonal quadrants; 2) full-mouth (FM) at partially selected sites (mesiobuccal and distolingual (MB-DL)) and 3) half-mouth (HM) at MB-DL.

¹ The perceived stress was assessed using a 10-item Perceived Stress Scale (Cohen et al., 1983).

² The perceived social support was evaluated using a 12-item Multidimensional Scale of Perceived Social Support (Zimet et al., 1988).

Periodontitis prevalence was defined based on recommendations for epidemiological studies developed by the Centers of Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) (Eke P et al., 2012):

- a. Moderate-severe periodontitis: CAL \geq 4 mm at \geq 2 interproximal sites or periodontal probing depth (PPD) \geq 5 mm at \geq 2 interproximal sites.
- b. Severe periodontitis: CAL \geq 6 mm at \geq 2 interproximal sites and PPD \geq 5 mm at \geq 1 interproximal site.

The periodontitis extent was defined as the mean (sd) percentage of interproximal sites with CAL \geq 3 mm or CAL \geq 5 mm, adjusted for the total number of sites per individual, based on the reporting standards of the joint European Union and United States of America Periodontal Epidemiology working group (Holtfreter et al., 2015).

2.4. Sample size

The calculated minimum sample size for multivariate logistic regression was based on the primary data collected from the first 100 subjects using the G*Power program, version 3.1.9.2 (Faul et al., 2009). The sample size required for moderate-severe periodontitis was 350 based on the current smoking variable, where the proportion of current smokers was 22.0%, Odds ratio (OR) = 2.9, α = 0.05, Power = 0.80, and R^2 = 0.450, whereas the minimal sample size required for studying severe periodontitis was 330, where OR = 2.6, α = 0.05, Power = 0.80, and R^2 = 0.263. An additional 81 subjects were recruited to account for anticipated missing data and to ensure a sufficient number of cases per included explanatory predictor for the multivariate regression models.

2.5. Assessment of the prevalence and extent of periodontitis

The statistical analyses were performed at the subject level using SPSS, version 27 software (IBM, Chicago, IL, USA). The accuracy for assessing the prevalence of periodontitis using three PRPs was compared to that for the FRP. The comparative analyses were performed using accuracy indicators: sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), which were calculated as given below.

$$\text{Sensitivity} = \frac{\text{true positives}}{(\text{true positives} + \text{false negatives})}$$

$$\text{Specificity} = \frac{\text{true negatives}}{(\text{true negatives} + \text{false positives})}$$

$$\begin{aligned} \text{Positive predictive value (PPV)} \\ = \frac{\text{true positives}}{(\text{true positives} + \text{false positives})} \end{aligned}$$

$$\begin{aligned} \text{Negative predictive value (NPV)} \\ = \frac{\text{true negatives}}{(\text{true negatives} + \text{false negatives})} \end{aligned}$$

The precision of estimating the prevalence and extent of disease was determined using the absolute bias (Kingman A et al., 2008).

$$\begin{aligned} \text{Absolute bias}_{\text{prevalence}} &= \text{Prevalence}_{\text{PRP}} - \text{Prevalence}_{\text{FRP}} \\ \text{Absolute bias}_{\text{extent}} &= \text{Extent}_{\text{PRP}} - \text{Extent}_{\text{FRP}} \end{aligned}$$

2.6. Assessment of risk associations of periodontitis

Multivariate logistic regression models were used to evaluate the magnitude of risk associations of periodontitis. The predictors considered in the multivariate model included age, perceived stress and perceived social support, which were recorded as continuous variables and subsequently divided into two categories based on the respective mean scores. Medical conditions were self-reported by the subjects. Only two of the subjects with diabetes mellitus reported glycemic control. Thus, subjects without glycemic control were compared to subjects with glycemic control and subjects without diabetes mellitus. Variables that lacked variation (i.e., variables with only a few cases in some categories) were excluded from the statistical analyses. The excluded variables were ethnicity, other medical conditions, use of medications, and plaque scores (uniformly high levels of plaque were observed, i.e., \geq 25% of dentitions were covered with plaque in $>$ 96.3% of the subjects). The regression analyses were performed using dummy variables for variables with \geq 3 categories. The absolute bias at the natural logarithm (LN) scale of the OR was calculated as follows (Akinkugbe et al., 2015):

$$\text{Absolute bias}_{\text{OR}} = \text{LN}(\text{OR}_{\text{PRP}}) - \text{LN}(\text{OR}_{\text{FRP}})$$

3. Results

A total of 431 subjects with a mean age (sd) of 35.4 (13.3) years were recruited. Among these subjects, 42.5% were males and 57.5% were females. The selection process for the study subjects based on the eligibility criteria is presented in Fig. 1. The number of present teeth ranged from 3 to 28 teeth, with a mean (sd) of 23.8 (5.2) teeth. The intraexaminer agreement using Cohen's kappa was 0.99 for the two CAL thresholds. The reliability of the repeated questionnaire item based on Cohen's kappa was 0.99. The internal consistency indicated by Cronbach's alpha was 0.77 for the perceived stress scale items and 0.99 for the perceived social support items.

The accuracy and precision of the prevalence and extent of periodontitis determined using three PRPs compared to those determined using the FRP are presented in Table 1. The prevalence of moderate-severe periodontitis was 68.4%, 68.7% and 58.7% determined using RHM, (FM)MB-DL, and (HM)MB-DL, respectively, compared to 78.4% using the FRP reference standard.

The specificity and PPV were 100% for all PRPs. Estimating the prevalence using the (FM)MB-DL protocol resulted in the highest overall accuracy and precision. The accuracy of estimating prevalence using (FM)MB-DL with the severe periodontitis threshold was compared to that using the moderate-severe periodontitis threshold: the sensitivity increased from 87.6% to 88.2%, the NPV increased from 68.9% to 94.9% and the absolute bias_{prevalence} decreased from -9.7% to -3.5%. A similar pattern was seen with the use of RHM; however, there was a decrease in the sensitivity when measuring severe periodontitis compared to measuring moderate-severe periodontitis. The lowest sensitivity, NPV and the highest absolute bias_{prevalence} were observed using (HM)MB-DL. The extent of periodontitis had a low absolute bias_{extent} that ranged

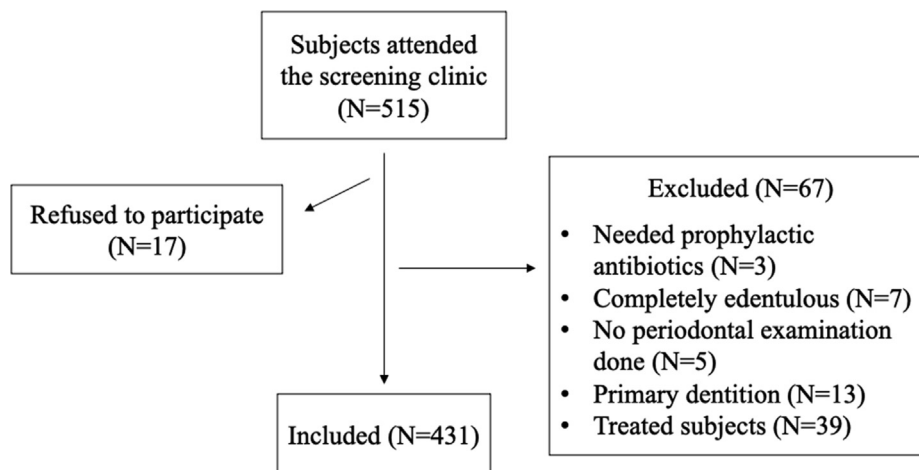


Fig. 1 Selection of study subjects.

Table 1 Accuracy and precision of estimating the periodontitis prevalence and extent at different disease thresholds using Partial-mouth Recording Protocols.

		FRP (reference) Total sites: 112	RHM Total sites: 56	(FM)MB-DL Total sites: 56	(HM)MB-DL Total sites: 28
Moderate-severe Periodontitis prevalence* (CAL \geq 4 mm at \geq 2 interproximal sites or PPD \geq 5 mm at \geq 2 interproximal sites)	Prevalence (%)	78.4	68.4	68.7	58.7
	Sensitivity (%)		87.3	87.6	74.9
	Specificity (%)		100.0	100.0	100.0
	Positive predictive value (%)		100.0	100.0	100.0
	Negative predictive value (%)		68.4	68.9	52.2
	Absolute bias _{prevalence} (%)			-10.0	-9.7
Severe Periodontitis Prevalence* (CAL \geq 6 mm at \geq 2 interproximal sites and PPD \geq 5 mm at \geq 1 interproximal site)	Prevalence (%)	31.3	23.4	27.8	18.4
	Sensitivity (%)		74.3	88.2	58.8
	Specificity (%)		100.0	100.0	100.0
	Positive predictive value (%)		100.0	100.0	100.0
	Negative predictive value (%)		89.4	94.9	84.0
	Absolute bias _{prevalence} (%)			-7.9	-3.5
Periodontitis Extent[†] at CAL \geq 3 mm	Extent mean% (sd)	34.9 (33.6)	33.9 (32.8)	32.6 (31.6)	33.1 (32.4)
	Absolute bias _{extent}		-1.0	-2.3	-1.8
Periodontitis Extent[†] at CAL \geq 5 mm	Extent Mean% (sd)	14.4 (25.6)	13.8 (25.1)	13.0 (23.9)	12.9 (24.2)
	Absolute bias _{extent}		-0.6	-1.4	-1.5

CAL: Clinical Attachment Loss, PPD: Periodontal Probing Depth, FRP: Full-mouth Recording Protocol, RHM: Random-Half-Mouth, MB: Mesiobuccal, DB: Distobuccal, ML: Mesiolingual, DL: Distolingual, (FM): Full-Mouth, (HM) Half-Mouth.

* Periodontitis prevalence is defined as proportion of subjects with periodontitis using case definitions by the Centers of Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) 2007, 2012.

† Periodontitis extent is defined as mean (sd) percentage of sites with interproximal CAL \geq 3 mm or \geq 5 mm adjusted for the total number of present sites per individual

from -0.6 to -2.3 for the three PRPs and two disease thresholds.

The distribution of moderate-severe periodontitis prevalence for different determinants is presented in Table 2. (HM)MB-DL resulted in the highest underestimations of moderate-severe periodontitis for all determinants among the

PRPs. The degree of underestimation using RHM and the (FM)MB-DL was similar to that using FRP.

The adjusted risk associations of moderate-severe and severe periodontitis are presented in Tables 3 and 4, respectively. The absolute bias_{OR} ranged from -0.8 to 0.8. The largest overall magnitude of bias_{OR} was obtained using (HM)MB-DL.

Table 2 Distribution of moderate-severe periodontitis per determinant using the Partial-mouth Recording protocols versus Full-mouth Recording Protocol.

Determinants		Subjects with moderate-severe periodontitis. N (%)			
		FRP	RHM	(FM)MB-DL	(HM)MB-DL
Age (in full years)	< 35	132 (61.4)	99 (46.0)	99 (46.0)	73 (34.0)
	35 +	206 (95.4)	196 (90.7)	197 (91.2)	180 (83.3)
Sex	Females	181 (73.6)	147 (59.8)	150 (61.0)	124 (50.4)
	Males	155 (84.7)	147 (80.3)	146 (79.8)	129 (70.5)
Level of Education	≤High school	120 (74.1)	98 (60.5)	98 (60.5)	79 (48.8)
	> High school	215 (80.8)	195 (73.3)	197 (74.1)	173 (65.0)
Household monthly income	Low < 5,000 Saudi Riyal	178 (74.5)	151 (63.2)	153 (64.0)	130 (54.4)
	High > 5,000 Saudi Riyal	157 (83.1)	142 (75.1)	142 (75.1)	122 (64.6)
Diabetes Mellitus	Glycemic control or normal	279 (76.0)	237 (64.6)	239 (65.1)	199 (54.2)
	No glycemic control	58 (92.1)	57 (90.5)	57 (90.5)	54 (85.7)
Obesity	No	265 (75.9)	228 (65.3)	230 (65.9)	197 (56.4)
	Yes	71 (88.8)	65 (81.3)	65 (81.3)	55 (68.8)
Cigarette Smoking	Never-smokers	227 (73.5)	190 (61.5)	192 (62.1)	158 (51.1)
	Former smokers	37 (88.1)	34 (81.0)	35 (83.3)	31 (73.8)
	Current smokers	72 (92.3)	69 (88.5)	68 (87.2)	63 (80.8)
Perceived Stress	Lower (≤42)	52 (24.4)	163 (76.9)	160 (75.5)	141 (66.5)
	Higher (≥42.1)	161 (75.6)	128 (60.1)	133 (62.4)	109 (51.2)
Perceived Social Support	Lower (<69.5)	166 (77.9)	145 (68.1)	151 (70.9)	123 (57.7)
	Higher (≥69.5)	167 (78.8)	146 (68.9)	142 (67.0)	127 (59.9)

FRP: Full-mouth Recording Protocol, RHM: Random-Half-Mouth, (HM): Half-Mouth, (FM): Full-Mouth, MB-DL: Mesiobuccal-Distolingual.

Table 3 Precision of estimating the adjusted risk associations with prevalence of CDC/AAP moderate-severe periodontitis (CAL ≥ 4 mm at ≥ 2 interproximal sites or PPD ≥ 5 mm at ≥ 2 interproximal sites).

Determinants		FRP (Reference)	RHM	(FM)MB-DL	(HM)MB-DL
		Nagelkerke R ² = 0.327	Nagelkerke R ² = 0.435	Nagelkerke R ² = 0.413	Nagelkerke R ² = 0.413
		OR (95% CI)	OR (95% CI) AB	OR (95% CI) AB	OR (95% CI) AB
Age (years)	< 35*	1.0	1.0	1.0	1.0
	35 +	12.0 (5.6–25.8)	10.2 (5.5–18.6)	–0.2 10.3 (5.6–18.8)	–0.2 8.5 (5.0–14.3) –0.4
Sex	Females*	1.0	1.0	1.0	1.0
	Males	1.1 (0.6–2.1)	1.7 (0.9–3.2)	0.5 1.5 (0.8–2.9)	0.4 1.3 (0.7–2.4) 0.2
Level of Education	> High school*	1.0	1.0	1.0	1.0
	≤High school	0.9 (0.5–1.6)	1.2 (0.7–2.0)	0.2 1.3 (0.8–2.9)	0.3 1.4 (0.9–2.4) 0.4
Household monthly income	Higher (≥5,000) Saudi Riyal *	1.0	1.0	1.0	1.0
	Lower (< 5,000) Saudi Riyal	2.1 (1.2–3.7)	2.8 (1.6–4.9)	0.3 2.3 (1.3–3.9)	0.1 2.0 (1.2–3.4) –0.1
Diabetes Mellitus	Other	1.0	1.0	1.0	1.0
	No glycemic control	0.9 (0.3–2.7)	1.6 (0.6–4.5)	0.6 1.5 (0.5–4.0)	0.5 1.9 (0.8–4.5) 0.8
Obesity	Other	1.0	1.0	1.0	1.0
	Obese	1.6 (0.7–3.7)	1.6 (0.8–3.3)	0.0 1.4 (0.7–2.9)	–0.1 1.1 (0.6–2.0) –0.4
Cigarettes Smoking	Never-smokers*	1.0	1.0	1.0	1.0
	Former smokers	1.5 (0.5–4.7)	1.2 (0.4–3.4)	–0.2 1.5 (0.6–4.3)	0.0 1.5 (0.6–3.8) 0.0
	Current smokers	4.2 (1.5–11.7)	4.0 (1.6–10.0)	–0.1 3.5 (1.5–8.5)	–0.2 4.1 (1.9–9.1) –0.1
Perceived Stress	Lower (≤42) *	1.0	1.0	1.0	1.0
	Higher (≥42.1)	0.8 (0.4–1.3)	0.4 (0.2–0.6)	–0.8 0.4 (0.3–0.8)	–0.6 0.5 (0.3–0.8) –0.5
Perceived Social Support	Higher (≥69.5) *	1.0	1.0	1.0	1.0
	Lower (< 69.5)	0.9 (0.5–1.5)	1.0 (0.6–1.8)	0.2 1.4 (0.8–2.4)	0.5 0.9 (0.6–1.5) 0.0

* Reference category, CAL: Clinical Attachment Loss, PPD: Periodontal Probing Depth, CDC: Centers of Disease Control and Prevention, AAP: American Academy of Periodontology, OR: Odds Ratio, R²: explained variance, CI: Confidence Interval, AB: Absolute Bias, FRP: Full-mouth Recording Protocol, RHM: Random-Half-Mouth, MB: Mesiobuccal, DL: Distolingual, (FM): FullMouth, (HM): HalfMouth

Table 4 Precision of estimating the adjusted risk associations with prevalence of CDC/AAP severe periodontitis (CAL \geq 6 mm at \geq 2 interproximal sites and PPD \geq 5 mm at \geq 1 interproximal site).

Determinants		FRP (Reference)		RHM		(FM)MB-DL		(HM)MB-DL	
		Nagelkerke $R^2 = 0.325$		Nagelkerke $R^2 = 0.326$		Nagelkerke $R^2 = 0.309$		Nagelkerke $R^2 = 0.280$	
		OR (95% CI)	OR (95% CI)	AB	OR (95% CI)	AB	OR (95% CI)	AB	
Age (years)	< 35*	1.0	1.0		1.0		1.0		
	35+	4.9 (2.9–8.3)	6.7 (3.5–12.7)	0.3	5.2 (3.0–9.0)	0.1	4.8 (2.5–9.4)	0.0	
Sex	Females*	1.0	1.0		1.0		1.0		
	Males	1.9 (1.1–3.6)	1.8 (0.9–3.6)	–0.1	1.9 (1.1–3.7)	0.0	2.4 (1.2–5.0)	0.2	
Level of Education	> High school*	1.0	1.0		1.0		1.0		
	\leq High school	2.0 (1.2–3.5)	2.2 (0.9–4.2)	0.1	2.0 (1.1–3.6)	0.0	1.8 (0.9–3.6)	–0.1	
Household monthly income	Higher (\geq 5,000) Saudi Riyal *	1.0	1.0		1.0		1.0		
	Lower (< 5,000) Saudi Riyal	1.7 (1.0–3.0)	1.4 (0.8–2.4)	–0.2	1.7 (0.9–2.9)	0.0	1.9 (1.0–3.5)	0.1	
Diabetes Mellitus (DM)	Other	1.0	1.0		1.0		1.0		
	No glycemic control	2.0 (1.1–3.8)	1.9 (0.9–3.7)	–0.1	1.6 (0.8–3.0)	–0.2	2.6 (1.3–5.1)	0.3	
Obesity	Non-obese	1.0	1.0		1.0		1.0		
	Obese	1.3 (0.7–2.4)	1.1 (0.5–2.0)	–0.2	1.4 (0.7–2.6)	0.1	0.8 (0.4–1.7)	–0.5	
Cigarettes Smoking	Never-smokers*	1.0	1.0		1.0		1.0		
	Former smokers	1.4 (0.6–3.2)	1.3 (0.5–3.1)	–0.1	1.3 (0.6–3.1)	–0.1	0.6 (0.2–1.6)	–0.8	
	Current smokers	2.3 (1.2–4.7)	2.5 (1.2–5.2)	0.1	2.2 (1.1–4.4)	–0.1	1.9 (0.9–4.1)	–0.2	
Perceived Stress	Lower (\leq 42) *	1.0	1.0		1.0		1.0		
	Higher (\geq 42.1)	0.6 (0.4–1.0)	0.7 (0.4–1.3)	0.2	0.6 (0.3–0.9)	0.0	0.9 (0.5–1.6)	0.4	
Perceived Social Support	Higher (\geq 69.5) *	1.0	1.0		1.0		1.0		
	Lower (< 69.5)	1.1 (0.7–1.9)	0.8 (0.5–1.4)	–0.3	1.3 (0.8–2.1)	0.1	1.1 (0.6–1.9)	0.0	

* Reference category, **CAL**: Clinical Attachment Loss, **PPD**: Periodontal Probing Depth, **CDC**: Centers of Disease Control and Prevention, **AAP**: American Academy of Periodontology, **OR**: Odds Ratio, **R²**: explained variance, **CI**: Confidence Interval, **AB**: Absolute Bias, **FRP**: Full-mouth Recording Protocol, **RHM**: Random-Half-Mouth, **MB**: Mesiobuccal, **DL**: Distolingual, **(FM)**: FullMouth, **(HM)**: HalfMouth.

4. Discussion

We compared the accuracy and precision of using PRPs and FRPs to estimate the prevalence, extent and risk associations of periodontitis in a sample of subjects who had not been treated for periodontitis. In previous studies, PRPs were used to assess untreated periodontitis cases without determining the accuracy or potential bias in estimating the prevalence and risk associations of the disease (Loe H et al., 1978; Timmerman M et al., 1998). In one study on the validity of using PRP in untreated subjects, a high correlation between the RHM and FRP was found, despite the use of different CAL thresholds (Dowsett et al., 2002a). The use of two thresholds for periodontitis diagnosis for our sample of untreated subjects resulted in prevalence rates from 31.3% to 78.4% and an extent of periodontitis from 14.4% to 34.9%. Both the prevalence and extent of periodontitis in our study subjects were high compared to other general populations (Susin et al., 2005; Tran et al., 2014, 2016). However, our findings were comparable with the prevalence and extent of untreated subjects in Guatemala (Dowsett et al., 2001, 2002b).

Based on our findings, the specificity and PPV were 100% for all PRPs, which was consistent with previous findings because PRPs can only be used to identify subjects with periodontitis that have already been identified using the FRP (Preisser et al., 2018; Tran et al., 2013). The measures of accu-

racy, i.e., the sensitivity and NPV, for (FM)MB-DL and RHM ranged from 68.4 to 94.9%, which indicates a moderate to high level of accuracy (Nelson D et al., 2001). The sensitivity and NPV of estimating the prevalence using (HM)MB-DL ranged from 52.2 to 84.0%.

Both the sensitivity and specificity are not impacted by differences in the prevalence of disease (Tenny S & Hoffman MR, 2021). However, the predictive values were impacted by the disease prevalence; thus, when the prevalence of severe periodontitis decreased compared to that of moderate-severe periodontitis, the NPV increased.

The overall accuracy and precision of estimating the prevalence using the CDC/AAP definitions ranged from low to moderate. The absolute bias_{prevalence} for moderate-severe periodontitis was lower than for severe periodontitis, which is consistent with previous studies (Romano et al., 2019; Tran et al., 2014). However, the sensitivity of the RHM and (HM)MB-DL was lower for measuring severe periodontitis than moderate-severe periodontitis, whereas the sensitivity of (FM)MB-DL was slightly higher for measuring severe periodontitis than moderate-severe periodontitis.

The absolute bias_{extent} for the extent of periodontitis was low for all three PRPs.

The precision of using the PRPs was also examined for studying potential risks associated with periodontitis, such as sociodemographic characteristics, medical conditions, smok-

ing, perceived stress and perceived social support. The magnitude of the risk associations obtained using the PRPs were either underestimated or overestimated compared to that obtained using FRP recordings, which is similar to the results of previous studies (Akinkugbe et al., 2015; Alshihayb et al., 2020). However, these variations in PRPs were within the range of the 95% confidence intervals of the FRP's ORs. The use of (HM)MB-DL resulted in the highest absolute bias_{OR} among the PRPs.

The absolute bias for ORs was smaller for severe periodontitis thresholds compared to moderate-severe periodontitis thresholds. A larger OR resulted in a smaller absolute bias_{OR}, as can be observed for age and current smoking, compared to other determinants with a smaller OR. These findings were consistent with those of a simulation study by Heaton *et al.* in which the direction and magnitude of bias were associated with the severity of the case definitions and the magnitude of the associations (Heaton, Garcia, et al., 2018).

The strength of this study is that several issues were addressed that have not been extensively analyzed in the literature. In this study, the accuracy and precision of estimating the prevalence, extent and risk associations were determined for a population that had never been treated for periodontal conditions. The limitations of our study are the use of a purposive sample recruited in a university setting, which may reduce the external validity of the findings. The medical conditions, including glycemic control, were self-reported by the subjects and not measured objectively.

5. Conclusions

Overall, PRPs were used to estimate the prevalence, extent and risk associations of untreated periodontitis with moderate to high accuracy. The (FM)MB-DL and RHM were PRPs with moderate to high levels of accuracy and precision for estimating the prevalence and risk associations of untreated periodontitis. The extent of periodontitis was estimated with high precision using RHM, (FM)MB-DL and (HM)MB-DL. The magnitude and direction of the bias were confirmed to be associated with the severity of periodontitis, selected PRPs and magnitude of risk associations. The authors recommend the use of the FRP for examining the prevalence, extent and risk associations of periodontal disease. However, when time and resources are limited, we recommend using (FM)MB-DL, the PRP with the highest overall accuracy and precision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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