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Prevalence of periodontitis: misclassification, under-recognition or over-diagnosis using partial and full-mouth periodontal examination protocols.

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ABSTRACT

Objective: The aim of this cross-sectional study was to assess the bias in estimating the prevalence of periodontitis due to partial-mouth periodontal examination protocols (PMPE) and to relate the severity and extent of periodontal damage to periodontitis misclassification when applying case definitions by Centres of Disease Control and Prevention and American Academy of Periodontology (CDC/AAP).

Materials and methods: A full-mouth periodontal examination (FMPE) was performed in 721 adults living in North Italy to identify moderate and severe periodontitis. These results were compared with those obtained with two PMPE protocols analysing two interproximal sites on all teeth (fMB-DL) or four interproximal sites in two random diagonal quadrants (pMDB-MDL).

Results: Both PMPE systems estimated the prevalence of moderate periodontitis with limited bias (-2.79% for pMDB-MDL and -3.49% for fMB-DL), whereas produced larger relative biases for severe periodontitis (-28.74% *versus* -14.55%). The percentage of under-recognition of existing periodontal disease was 8.9% under fMB-DL and 15.5% under pMDB-MDL. The diagnosis of moderate and severe periodontal disease was correctly assigned to individuals with on average 8% and 30% of pathological sites, respectively.

Conclusion: These findings suggest that PMPE systems provide high level of bias when using CDC/AAP case definitions.

Key words: bias (epidemiology); cross-sectional study; dental health surveys; periodontitis; population surveillance.

Introduction

Public health administrators can only access imprecise estimates of periodontal disease within populations and uncertain assessments of risk factor influencing its morbidity rate [1,2]. The accuracy of prevalence estimates of periodontitis is influenced by the examination protocol used and by disease distribution according to age and case definition methods [3-6].

A protocol consisting of full-mouth periodontal examination (FMPE) at six sites per tooth is at present the gold standard method for assessing periodontal disease status of individuals and is routinely used in periodontal clinics. However, due to logistic considerations and constraints of time and cost [7-10], periodontitis is commonly assessed through partial-mouth periodontal examination protocols (PMPE) involving the examination of a subset of teeth and sites [11,12]. Different PMPE protocols have been proposed in the literature [13], but all of them have shown various degrees of underestimation of the prevalence of periodontal disease in the population, determined by the FMPE [2,7,11,14], while severity can be either under- or overestimated [3,15].

A universally accepted case definition of periodontitis that incorporates appropriate combinations of extension (percentage of affected sites) and severity (magnitude of periodontal destruction) values has not been yet established [5,16]. The epidemiologic hallmark of periodontitis is destruction of tooth-supporting tissues, manifested as clinical attachment loss (CAL), increased probing depth (PD) and radiographic bone loss. A sharp distinction between periodontal health and disease is quite arbitrary and epidemiologic case definitions rely on different cut-off values used to define levels of clinical periodontal disease [16].

In 2007 the Centres for Disease Control and Prevention (CDC) in collaboration with the American Academy of Periodontology (AAP) developed case definitions of moderate and

severe periodontitis for use in epidemiologic surveys [17]. Recently, the Joint EU/USA Periodontal Epidemiology Working Group recommended the above case definitions as standardized periodontitis classification in population-based surveillance and FMPE as the gold standard method for periodontal disease detection [18]. A PMPE protocol could be used in case of limited resources [18].

Two of the most used partial sampling methods in large epidemiologic surveys are the full-mouth two sites and the random diagonal quadrant six-sites protocol. They have been demonstrated the most accurate among adolescents, young and older adults [14,15,19,20]. The accuracy of these PMPE protocols in estimating the prevalence of periodontitis according to CDC/AAP case definitions was evaluated in the NANHES 2009-2010 and 2011-2012 datasets [21,22]. They provided more precise estimates in conjunction with half-reduced CDC/AAP case definitions [21,22].

It is known that the accuracy of PMPE systems is directly related to the extent and severity of periodontal diseases in a population and to the case definition applied [23]. Nonetheless, evaluations of the impact of the extent of periodontitis on the misclassification of periodontitis (patients shifting from one CDC/AAP category to another) and on the resulting under-recognition (failure to recognize an existing periodontal disease) and over-diagnosis (over-recognition of a periodontal disease category) have been lacking.

Hence, the primary aim of this study was to assess the accuracy in estimating the prevalence of periodontitis in an adult population from North Italy using PMPE protocols and CDC/AAP case definitions. The secondary aim was to explore the impact of severity and extent of periodontal damage on misclassification under PMPE.

Materials and methods

Study population

PMPE and FMPE protocols performances were evaluated using existent data from a cross-sectional population-based epidemiologic survey for periodontitis collected between December 1, 2009 and July 31, 2010 by the Section of Periodontology, C.I.R. Dental School, Department of Surgical Sciences, University of Turin (Italy) [24]. The original sample included 736 adults living in the city of Turin, an industrialized area in North-West of Italy, randomly selected by a stratified two-stage probability sampling method from the Health Regional Register of Piedmont. This administrative database collects demographic data of the entire population covered by the Regional Health Service and information about general practitioners (GP) to whom they are assigned. The primary sampling units were GPs stratified by the four health care districts of Turin, and the second stage units were the subjects cared for by each GP, who were sampled using a random sampling technique. Detailed information concerning the sampling method and the methodological procedures of the previous survey has been published elsewhere [24].

Individuals with < 6 teeth were excluded from the original dataset as several PMPE protocols had missing values for them [21] (Fig. 1). The final study population comprised 721 dentate individuals, aged between 20 and 75 years. The survey was approved by the Institutional Research Ethics Committee (Protocol no. 0082388), and written informed consent was obtained from each participant in accordance with the Declaration of Helsinki.

Periodontal examination

Study participants underwent a periodontal examination by one experienced and calibrated periodontist (SP). The correlation coefficients values within the survey examiner and between him and the expert reference examiner ranged between 0.90-0.99 and between 0.88-0.95, respectively. The weighted kappa coefficient (within ± 1 mm) for sites with PD ≥ 4 mm was 0.87 (95% IC 0.82, 0.92) [24].

Periodontal examinations were performed using a headlight and a manual periodontal probe with 1-mm markings (PCPUNC15, Hu-Friedy®, Chicago, IL, USA). PD and gingival recession were measured at six sites per tooth [mesio-buccal (MB), mid-buccal (B), disto-buccal (DB), mesio-lingual (ML), mid-lingual (L) and disto-lingual (DL)]. CAL was calculated as the sum of PD and gingival recession, and represented the distance from the cemento-enamel junction to the bottom of the pocket/sulcus. Measurements were rounded to the nearest lower millimetre. No radiographic examination was made.

Outcome definition

Periodontal status was established using a rule-based algorithm based on operational definitions of moderate and severe periodontitis outlined by CDC/AAP [17]. Specifically, individuals were classified as having moderate periodontitis if 2 or more interproximal sites, on separate teeth, had a CAL of ≥ 4 mm or 2 or more interproximal sites had a PD of ≥ 5 mm, not on the same tooth. Severe periodontitis was recorded if 2 or more interproximal sites had a CAL of ≥ 6 mm, not on the same tooth, and if at least 1 interproximal site had a PD of ≥ 5 mm. Otherwise individuals not meeting case definitions of moderate or severe periodontitis were classified as having no/mild periodontitis [21, 25].

Full-mouth examination (reference)

The reference estimates of moderate and severe periodontitis were assumed to be those obtained using FMPE protocol consisting of measurements of PD and CAL at six sites around each tooth excluding third molars [17]. As only interproximal sites contributed to the CDC/AAP case definition, the method produces a maximum of 112 sites in the fully dentate.

Partial-mouth recording protocols

All partial-mouth datasets were derived from full-mouth data. Third molars and measurements on mid-buccal and mid-lingual sites were excluded according to the

CDC/AAP case definition [17]. Two PMPE systems were compared to the FMPE results. They were the full-mouth mesio-buccal-disto-lingual protocol (fMB-DL) and the diagonal half-mouth four sites protocol using the mesio-buccal, disto-buccal, mesio-lingual and disto-lingual sites (pMDB-MDL). A maxillary quadrant with its corresponding contralateral mandibular quadrant was randomly selected by using Stata's random-number function. These protocols have been demonstrated the most accurate in estimating periodontitis prevalence among all PMPE methods tested in the literature [7,14,21]. Both methods examine a maximum of 56 sites per individual.

Data analysis

In order to produce estimates of moderate and severe periodontitis prevalence, each age and sex stratum was weighted for the inverse of the probability to be selected using as reference the population in Turin at 01/01/2010 (data from the National Institute of Statistics). We estimated the sensitivity of each PMPE protocol to detect severe periodontitis and to identify cases of periodontitis irrespective of the degree of disease severity. Because healthy subjects could not be misclassified, specificity was equal to 1 by definition [3]. We used the STATA *survey* commands in order to consider the design effect on the periodontitis prevalence.

The prevalence estimated by PMPE protocols of moderate and severe periodontitis alone and in combination (moderate-severe) was compared with the corresponding prevalence estimated by FMPE; absolute bias was defined as the difference in prevalence estimated by PMPE and prevalence estimated by FMPE (reference) and relative bias was calculated as the ratio between absolute bias and the prevalence estimated by FMPE [11]. We tested if absolute bias in severe periodontitis was less than 0 using 1-tailed Z-test and if absolute bias was different from 0 in moderate periodontitis using 2-tailed Z-test (stata command

prtest). PMPE protocol associated absolute bias for prevalence estimate was stratified by age groups at 10-year intervals and gender, and tested with Z-test.

Then, we assessed the mean percentage of sites with PD ≥ 4 mm or PD ≥ 6 mm according to whether PMPE determinations of moderate or severe periodontitis in each participant were concordant or discordant with diagnosis made under the FMPE protocol. Statistical analysis was conducted using the Statistical Package STATA/SE 13.1 (Stata Corp LP, College Station, TX, USA).

Results

The sociodemographic, lifestyle and medical characteristics of the 721 study participants are presented in Table 1 according to the 3 periodontal health status categories (i.e. no/mild periodontitis, moderate and severe periodontitis) based on the FMPE protocol.

The fMB-DL misclassified 49 (17.1%) individuals with moderate periodontitis as no/mild periodontitis, 39 (14.2%) with severe periodontitis as moderate periodontitis and one as no/mild periodontitis (Table 2). Worse results were obtained with the pMDB-MDL protocol. It misclassified 78 (27.2%) cases of moderate periodontitis as no/mild periodontitis, 70 (25.5%) with severe periodontitis as moderate and 9 (3.3%) as no/mild periodontitis. The percentage of false negatives was 8.9% under fMB-DL and 15.5% under pMDB-MDL.

In terms of accuracy (Table 3), PMPE systems demonstrated a range of sensitivity of 84.52% to 91.10% for detecting periodontitis. The lowest sensitivity was obtained in the pMDB-MDL protocol (71.27%) to detect the severe form of disease.

As seen in Table 4, FMPE prevalence estimates of moderate and severe periodontitis were 39.81% (95% CI: 36.23, 43.38) and 38.14% (95% CI: 34.60, 41.69), respectively. Prevalence of moderate periodontitis estimated by using fMB-DL and pMDB-MDL systems were close to the FMPE reference prevalence with an absolute bias respectively

equal to -1.39% and to -1.11%. The relative biases were -3.49% and -2.79%. Prevalence of severe periodontitis was underestimated both using fMB-DL protocol (absolute bias = -5.55%, relative bias = -14.55%) and using pMDB-MDL protocol (absolute bias = -10.96%, relative bias = -28.74%,).

Similar results were obtained for the prevalence of moderate-severe periodontitis (fMB-DL absolute bias = -6.93% and relative bias = -8.89%; pMDB-MDL absolute bias = - 12.07% and relative bias = -15.48%).

Appendix Table 1 summarized prevalence estimates and associated bias for each PMPE protocol stratified by age and gender. The amounts of bias in disease estimates were statistically significant only for severe periodontitis in age groups over 40 under the pMDB-MDL protocol. The biases associated with both PMPE protocols were not related to the gender.

Table 5 relates the misclassification of periodontitis to the mean percentage of sites (extension) above two different thresholds of PD. Subjects correctly diagnosed as having no/mild periodontitis had a mean percentage of sites with PD ≥ 4 mm of 0.23% (range 0.00% to 5.88%). This percentage increased to 1.93% (range 0.00% to 6.06%) among 50 individuals (49 moderate and 1 severe periodontitis) misclassified as no/mild periodontitis based on the fMB-DL protocol and to 2.87% (range 0.00% to 14.29%) among 87 individuals (78 moderate and 9 severe periodontitis) misclassified under the pMDB-MDL system. The mean percentage of sites with PD ≥ 6 mm was 2.49% for cases of severe periodontitis misclassified as no/mild based on the pMDB-MDL system, whereas cases of severe periodontitis misclassified as moderate had percentage of 1.26% and 2.15% under fMB-DL and pMDB-MDL protocol, respectively.

The diagnosis of moderate and severe periodontal disease was correctly assigned to individuals with on average 8% and 30% of sites with PD ≥ 4 mm, respectively.

Table 6 summarizes the percentage of subjects examined who had at least one site with PD ≥ 4 or ≥ 6 mm (severity) in relation to the accuracy of periodontal diagnosis. Using the FMPE approach, 78.6% of individuals in the healthy/no mild periodontitis and 4.9% of those with moderate periodontitis had no sites with PD ≥ 4 mm, while 11.3% of subjects with severe periodontitis had no sites with PD ≥ 6 mm. Approximately 20.0% of severe periodontitis misclassified as moderate had no site with ≥ 6 mm PD under both PMPE protocols.

Discussion

This study presents the differences in the prevalence estimates of moderate and severe periodontitis by applying the same CDC/AAP case definition to both full-mouth and partial-mouth protocols in an adult European population [17]. As the accuracy of a PMPE protocol may be associated with demographic characteristics, extension and severity of periodontal disease and number of lost tooth, the amount of underestimation may vary among different populations [2,9,23]. It is well established that tooth loss increased with age and may affect the estimates of periodontal disease [26]. As would be expected, individuals with greater amount of attachment loss are more likely to lose teeth over the next years [27]. Additionally, the type and number of sites assessed and those included in the case definition also affect the magnitude of PMPE bias [2,7].

Two of the most used partial sampling methods to reduce time and cost for periodontal examination in large epidemiologic surveys are the full-mouth MB-B-DL and the random diagonal quadrant six-sites. Several previous studies found that these PMPE systems provided a sensitivity of ≥ 90% for estimating prevalence of CAL ≥ 4 mm [7,11,28] and PD ≥ 4 mm [11,28]. The PMPE half-mouth protocol produced a relative bias of less than 4% for CAL extent but of 0% for PD extent [20,28]. A small relative bias was also obtained for

prevalence estimates of moderate (CAL or PD ≥ 4 mm) and severe (CAL or PD ≥ 6 mm) periodontitis when using the full-mouth MB–B–DL [20].

In the literature, only four studies in the United States population assessed the bias associated with PMPE protocols in estimating periodontitis prevalence using the case definitions of CDC/AAP [2,21,22,25]. Eke et al. demonstrated that a random half-mouth protocol that examines only the interproximal buccal sites underestimated the true prevalence of moderate and severe periodontitis by 59% and 50%, respectively [2,25]. These relative biases decreased to -11% and -27% for the fMB-DL system and to -18% and -35% for the pMDB-MDL protocol [21]. However, when applying a half-reduced CDC/AAP case definition both PMPE methods provided smaller relative biases for severe periodontitis (-8.2% and -1.5%), but the corresponding biases for moderate periodontitis were 11.4% and 15.9%, respectively [22].

In the present investigation a relative bias of approximately -3% in moderate periodontitis prevalence was provided by both PMPE systems, whereas a larger bias in the estimate of severe periodontitis prevalence was obtained by the pMDB-MDL protocol (-28.74%) compared to the fMB-DL system (-14.55%). The corresponding absolute biases were 10.96% and 5.55%, respectively. Accordingly, the sensitivity was 71.27% and 85.45%. Sensitivity values ≥ 80% were considered of high validity for PMPE protocols in epidemiologic surveys [7,29].

The present findings were better than those previously reported in the adult U.S. population for moderate and severe periodontitis when using full CDC/AAP definitions and for moderate periodontitis when applying a half-reduced CDC/AAP definition [21,22]. Interestingly, in the NANHES datasets the pMDB-MDL protocol performed well for periodontitis surveillance across all strata of age, whereas in the current study it largely underestimated severe periodontitis prevalence among individuals older than 40 years.

Given, these data, both CDC/AAP epidemiologic definitions resulted in a certain degree of bias, strictly dependent upon the population under study. It can be hypothesized that the performance of the PMPE systems may be affected by the prevalence rates and severity of periodontitis in the Italian population. As reported by Kingman et al. the relative bias increased when disease prevalence decreased [3].

Another aspect to be addressed was the impact of the extent and severity of periodontal disease on the performance of PMPE protocols. The current data indicated that bias in the prevalence estimates of periodontitis might be more directly related to the type of sites examined, rather than to the number. Using the full-mouth measure of only two interproximal sites, the percentage of under-recognition of existing periodontal disease was 8.9%. When examining 4 interproximal sites per tooth in a half-mouth basis, it increased to 15.5%, despite both methods produce 56 sites per individual. These results corroborate previous findings showing that MB-B-DL full-mouth protocol has lower bias and higher sensitivity than random six-sites half-mouth system [7,11].

According to previous epidemiologic studies, periodontal pockets were categorized based on threshold PD values of ≥ 4 mm and ≥ 6 mm [1,4,20,30,31]. Moderate periodontitis cases misclassified as non-cases had a mean percentage of pockets ≥ 4 mm of 2.0%. A similar percentage was detected for severe periodontitis misclassified as non-cases when considering pathological sites ≥ 6 mm. From a clinical point of view, this implies that PMPE systems are not suitable for an early detection of periodontitis, especially in the most aggressive forms.

Regarding the impact of severity of periodontal disease, 78.6% of individuals with no/mild periodontitis under FMPE protocol had no pathological sites. However, it is important to underline that in agreement with Tran et al. [21] we used the three-level CDC/AAP

classification, thus we did not assess if the remaining individuals met the criteria for mild periodontitis.

Interestingly, 4.9% of those diagnosed with moderate periodontitis showed no sites with PD ≥ 4 mm and 11.3% of subjects with severe periodontitis no sites with PD ≥ 6 mm. In such individuals the diagnosis of periodontitis was assigned only on CAL values (indicator of past tissue destruction). One or two isolated sites of CAL ≥ 4 mm might reflect local phenomena (overhanging restorations, proximal caries, gingival recession after periodontal therapy) and not active periodontal disease [32,33]. This may represent a limit of CDC/AAP algorithms. In general, the extension of disease in the population under study would seem to play a more relevant role in periodontitis misclassification that disease severity.

In addition to limitation due to sample size, the current study included only individuals from an adult population in North Italy. Thus, these findings need to be cautiously interpreted when considering other populations. The degree of bias may vary with the prevalence of disease when specific PMPE protocols are used. It is also important to emphasize that the misclassification of periodontitis by each PMPE system is directly related to the case definition applied.

We limited our evaluation to the 2007 CDC/AAP definitions and therefore the present data cannot be extrapolated to other periodontitis case definitions. CDC/AAP case definitions were developed based on very stringent specific criteria to capture moderate and severe periodontitis in epidemiologic surveys but they are less suitable in a clinical setting [17,34]. These algorithms may be useful in the early identification of localized severe periodontitis, but may lead to an over-diagnosis of moderate cases. On this basis, an improvement of CDC/AAP algorithm would need to be introduced to enhance adherence to the clinical requirements. In agreement with Papapanou and Susin [16], it may be argued the

introduction of epidemiologic definitions of periodontitis that take into account age cohort-related characteristics, incorporate measures of gingival inflammation, and allow a differential diagnosis between active disease and past tissue loss.

Conclusions

Both PMPE protocols provided large underestimation of the prevalence of severe periodontitis, with the pMDB-MDL protocol performing the worst under the study conditions. The percentage of false negatives was 8.9% under fMB-DL, and 15.5% under pMDB-MDL. As expected, the degree of misclassification was influenced by number of diseased sites. The under-recognition of severe periodontitis resulted in an overflow in the moderate category mainly in the middle-aged and older adults. In spite of the advantage of requiring less resource, the present findings show that use of the PMPE protocols has limited applicability in periodontitis surveillance, when CDC/AAP algorithms are used in combination.

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Disclosure statement

There was no conflict of interest.

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Figure legends

Figure 1. Flow chart of the study.

Supplemental material

Appendix Table 1. Absolute bias and 95% confidence interval of PMPE protocols in estimating prevalence of moderate and severe periodontitis by age and gender**.**

Table. 1 Characteristics of the study population according to the severity of periodontitis based on full-mouth examination protocol (FMPE).

Variable	No/ mild periodontitis	Moderate periodontitis	Severe periodontitis	Total
	No. (%)	**No. (%)**	**No. (%)**	**No. (%)**
Gender				
Female	104 (24.4)	181 (42.4)	142 (33.3)	427 (59.2)
Male	55 (18.7)	106 (36.1)	133 (45.2)	294 (40.8)
Age group, years				
<40	85 (43.4)	85 (43.4)	26 (13.3)	196 (27.2)
40-49	34 (21.4)	70 (44)	55 (34.6)	159 (22.1)
50-59	22 (11.8)	65 (34.9)	99 (53.2)	186 (25.8)
60-75	18 (10.6)	67 (34.4)	95 (55.9)	170 (24.9)
Number of teeth				
6 - 19	12 (7.5)	33 (11.5)	50 (18.2)	95 (13.2)
20 - 27	37 (23.3)	122 (42.5)	147 (53.5)	306 (42.4)
28 - 32	110 (69.2)	132 (46.0)	78 (28.3)	320 (44.4)
Education				
Primary/secondary school	41 (14)	119 (40.8)	132 (45.2)	292 (40.5)
High school	70 (24.8)	110 (39)	102 (36.2)	282 (39.1)
University	48 (32.7)	58 (39.5)	41 (27.9)	147 (20.4)
Smoker				
No smoker	134 (14.7)	222 (40.3)	195 (35.4)	551 (76.4)
Smoker	25 (14.7)	65 (38.2)	80 (47.1)	170 (23.6)
History of cardiovascular diseases				
No	158 (22.7)	276 (39.7)	262 (37.6)	696 (96.5)
Yes	0 (0)	7 (46.7)	8 (53.3)	15 (2.1)
Don't know	1 (10)	4 (40)	5 (50)	10 (1.4)
History of diabetes				
No	155 (23.1)	268 (39.9)	249 (37.19	672 (93.2)
Yes	3 (7.5)	15 (37.5)	22 (55)	40 (5.5)
Don't know	1 (11.1)	4 (44.4)	4 (44.4)	9 (1.2)
Total	**159 (22.1)**	**287 (39.8)**	**275 (38.1)**	**721 (100)**

Table 2. Diagnostic agreement between FMPE and PMPE protocols.

	FMPE			
	No/mild periodontitis	**Moderate periodontitis**	**Severe periodontitis**	**Total**
	N	**N**	**N**	**N**
fMB-DL				
No/mild periodontitis	159	49	1	209
Moderate periodontitis	0	238	39	277
Severe periodontitis	0	0	235	235
pMDB-MDL				
No/mild periodontitis	159	78	9	246
Moderate periodontitis	0	209	70	279
Severe periodontitis	0	0	196	196
Total	**159**	**287**	**275**	**721**

FMPE: full-mouth periodontal examination protocol (reference standard); PMPE: partial-mouth periodontal examination protocol; .fMB-DL: partial protocol considering mesiobuccal and distolingual sites on all teeth in the mouth; pMDB-MDL: partial protocol considering all interproximal sites on all teeth in two random diagonal quadrants.

Table 3. Sensitivity (SE) of PMPE protocols with respect to FMPE protocol (reference)

	SE (%)	95% Confidence Interval
Moderate and severe *versus* no/mild periodontitis		
fMB-DL	91.10	89.03, 93.18
pMDB-MDL	84.52	81.88, 87.16
Severe *versus* moderate or no/mild periodontitis		
fMB-DL	85.45	82.88, 88.03
pMDB-MDL	71.27	67.97, 74.58

FMPE: full-mouth periodontal examination protocol (reference standard); PMPE: partial-mouth periodontal examination protocol; fMB-DL: partial protocol considering mesiobuccal and distolingual sites on all teeth in the mouth; pMDB-MDL: partial protocol considering all interproximal sites on all teeth in two random diagonal quadrants.

Table 4. Absolute and relative bias of PMPE protocols in estimating prevalence of periodontitis according to CDC/AAP case definition.

	Prevalence (%)	95% Confidence Interval	Absolute bias (%)	95% Confidence Interval	*p* Value	Relative bias (%)
Moderate periodontitis						
FMPE	39.81	36.23, 43.38	Ref			Ref
fMB-DL	38.42	34.87, 41.97	-1.39	-6.42, 3.65	0.589*	-3.49
pMDB-MDL	38.70	35.14, 42.25	-1.11	-6.15, 3.93	0.629*	-2.79
Severe periodontitis						
FMPE	38.14	34.60, 41.69	Ref			Ref
fMB-DL	32.59	29.17, 36.01	-5.55	,-0.62, 10.47	0.0014**	-14.55
pMDB-MDL	27.18	23.94, 30.43	-10.96	-15.77, -6.15	< 0.0001**	-28.74
Moderate and severe periodontitis						
FMPE	77.95	74.92, 80.97	Ref			Ref
fMB-DL	71.01	67.70, 74.32	-6.93	-11.42, -2.45	0.001**	-8.89
pMDB-MDL	65.88	62.42, 69.34	-12.07	-16.66, -7.47	0.001**	-15.48

FMPE: full-mouth periodontal examination protocol (reference standard); PMPE: partial-mouth periodontal examination protocol; .fMB-DL: partial protocol considering mesiobuccal and distolingual sites on all teeth in the mouth; pMDB-MDL: partial protocol considering all interproximal sites on all teeth in two random diagonal quadrants.

*2-tailed **1-tailed

Table 5. Misclassification of periodontitis according to the mean percentage of sites (extension) above two different thresholds of PD.

Examination method		**% sites PD ≥ 4 mm**
	N subjects	**Mean ± SD**
fMB-DL		
No/mild periodontitis correctly classified	159	0.23 ± 0.64
Moderate periodontitis misclassfied as no/mild periodontitis	49	1.95 ± 1.09
Moderate periodontitis correctly classified	238	7.42 ± 8.97
Severe periodontitis misclassified as no/mild periodontitis	1	1.19
Severe periodontitis misclassified as moderate	39	13.33 ± 15.18
Severe periodontitis correctly classified	235	29.12 ± 21.70
Periodontitis misclassfied as no/mild periodontitis	*50*	*1.93 ± 1.10*
pMDB-MDL		
No/mild periodontitis correctly classified	159	0.23 ± 0.64
Moderate periodontitis misclassified as no/mild periodontitis	78	2.46 ± 1.91
Moderate periodontitis correctly classified	209	7.99 ± 9.38
Severe periodontitis misclassified as no/mild periodontitis	9	6.38 ± 4.45
Severe periodontitis misclassified as moderate	70	14.23 ± 16.48
Severe periodontitis correctly classified	196	31.84 ± 21.60
Periodontitis misclassfied as no/mild periodontitis	*87*	*2.87 ± 2.17*

Examination method		**% sites PD ≥ 6 mm**
fMB-DL	**N subjects**	**Mean ± SD**
No/mild periodontitis correctly classified	159	0.04 ± 0.40
Moderate periodontitis misclassified as no/mild periodontitis	49	0.09 ± 0.23
Moderate periodontitis correctly classified	238	0.27 ± 0.87
Severe periodontitis misclassified as no/mild periodontitis	1	1.19
Severe periodontitis misclassified as moderate	39	1.26 ± 1.03
Severe periodontitis correctly classified	235	8.06 ± 10.11
Periodontitis misclassified as no/mild periodontitis	*50*	*0.11 ± 0.23*
pMDB-MDL		
No/mild periodontitis correctly classified	159	0.04 ± 0.40
Moderate periodontitis misclassified as no/mild periodontitis	78	0.15 ± 0.42
Moderate periodontitis correctly classified	209	0.27 ± 0.90
Severe periodontitis misclassified as no/mild periodontitis	9	2.49 ± 1.63
Severe periodontitis misclassified as moderate	70	2.15 ± 3.04
Severe periodontitis correctly classified	196	9.04 ± 10.68
Periodontitis misclassified as no/mild periodontitis	*87*	*0.39 ± 0.55*

PMPE: partial-mouth periodontal examination protocol; fMB-DL: partial protocol considering mesiobuccal and distolingual sites on all teeth in the mouth; pMDB-MDL: partial protocol considering all interproximal sites on all teeth; PD: probing depth.

Table 6. Misclassification of periodontitis according to the prevalence of PD at different thresholds (severity).

Examination method	PD ≥ 4 mm		PD ≥ 6 mm		Total
	0 site	≥1 site	0 site	≥1 site	
	N (%)	N (%)	N (%)	N (%)	N
FMPE					
No/mild periodontitis	125 (78.6)	34 (21.4)	155 (97.5)	4 (2.5)	159
Moderate periodontitis	14 (4.9)	273 (95.1)	224 (78.1)	63 (21.9)	287
Severe periodontitis	0 (0)	275 (100)	31 (11.3)	244 (88.7)	275
fMB-DL					
No/mild periodontitis correctly classified	125 (78.6)	34 (21.4)	155 (97.5)	4 (2.5)	159
Moderate periodontitis misclassfied as no/mild periodontitis	2 (4.1)	47 (95.9)	42 (85.7)	7 (14.3)	49
Moderate periodontitis correctly classified	12 (5.0)	226 (95.0)	182 (76.5)	56 (23.5)	238
Severe periodontitis misclassified as no/mild periodontitis	0 (0)	1 (100)	0 (0)	1 (100)	1
Severe periodontitis misclassified as moderate	0 (0)	39 (100)	8 (20.5)	31 (79.5)	39
Severe periodontitis correctly classified	0 (0)	235 (100)	23 (9.8)	212 (90.2)	235
pMDB-MDL					
No/mild periodontitis correctly classified	125 (78.6)	34 (21.4)	155 (97.5)	4 (2.5)	159
Moderate periodontitis misclassified as no/mild periodontitis	6 (7.7)	72 (92.3)	65 (83.3)	13 (16.7)	78
Moderate periodontitis correctly classified	8 (3.8)	201 (96.2)	159 (76.1)	50 (23.9)	209
Severe periodontitis misclassified as no/mild periodontitis	0 (0)	9 (100)	0 (0)	9 (100)	9
Severe periodontitis misclassified as moderate	0 (0)	70 (100)	14 (20.0)	56 (80.0)	70
Severe periodontitis correctly classified	0 (0)	196 (100)	17 (8.7)	179 (91.3)	196

FMPE: full-mouth periodontal examination protocol (reference standard); PMPE: partial-mouth periodontal examination protocol; fMB-DL: partial protocol considering mesiobuccal and distolingual sites on all teeth in the mouth; pMDB-MDL: partial protocol considering all interproximal sites on all teeth in two random diagonal quadrants.

Figure 1 Flow chart of the study