Assessing Periodontitis in Populations: A Systematic Review of the Validity of Partial Mouth Examination Protocols

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Abstract

Objective—To estimate bias associated with partial mouth periodontal examination (PMPE) protocols regarding estimates of prevalence, severity and extent of clinical attachment loss (CAL), pocket depth (PD) and gingival recession (REC).

Material and Methods—A search was made for articles published in English, from 1946–2012, which compared PMPE *vs.* full mouth periodontal examination (FMPE) protocols for CAL or PD 4mm or REC 3mm thresholds. PMPE protocols were evaluated for sensitivity of estimates of periodontitis prevalence, relative biases for severity and extent estimates.

Results—A review of the literature identified 12 studies which reported 32 PMPE protocols. Three PMPE protocols which had sensitivities 85% and relative biases 0.05 in absolute values for severity and extent estimates were: 1) half mouth six-sites, 2) diagonal quadrants six-sites and 3) full mouth mesiobuccal-midbuccal-distobuccal (MB-B-DB). Two other PMPE protocols (full mouth and half mouth mesiobuccal-midbuccal-distolingual) performed well for prevalence and severity of periodontitis; however, their performance in estimates of extent was unknown.

Conclusions—Among the 32 PMPE protocols listed, the half-mouth six-sites and full-mouth MB-B-DB protocols had the highest sensitivities for prevalence estimates and lowest relative biases for severity and extent estimates.

Keywords

Periodontal indices; periodontitis; partial mouth examination protocols; periodontitis prevalence

Introduction

Full mouth periodontal examinations (FMPEs) are considered the "gold standard" to determine the periodontal status of an individual. While a comprehensive examination is feasible as part of routine dental care, full mouth examinations are time and resource consuming for epidemiological studies. FMPEs can take an average of 28.8 minutes (Owens et al., 2003) to measure periodontal probing depths (PD) and gingival recession (REC), or 40 minutes (Benigeri et al., 2000) to measure PD, bleeding on probing, calculus and clinical attachment loss (CAL) per individual. The FMPE process fatigues patients and examiners,

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which leads to measurement errors and large dropout rates (Kingman et al., 2008). Therefore, a partial mouth periodontal examination (PMPE) protocol which assesses fewer sites yet, still estimating the overall periodontal status is used for population-based studies, when budget restrictions and time constraints are found.

A PMPE protocol is defined as a clinical assessment of a representative set of teeth or sites within the individual (Kingman and Albandar, 2002). PMPE protocols include either indexed teeth of existent periodontal indices such as Periodontal Disease Index (Kingman et al., 2008) or a subgroup of probing sites and/or teeth such as the National Health and Nutrition Examination Survey (NHANES) IV protocol (Eke et al., 2010). The NHANES IV protocol randomly selected one maxillary quadrant and one mandibular quadrant and examined three fixed sites per tooth (mesiobuccal, midbuccal and distobuccal) (Dye and Thornton-Evans, 2007).

Since 1972, significant efforts toward the evaluation of PMPE protocols performance compared to a FMPE protocol have been published (Leroy et al., 2010, Downer, 1972). However, the aforementioned PMPE protocols have shown inconsistent results in estimates of periodontitis diagnosis. Although several PMPE protocols produced small biases for estimates of disease severity (Kingman et al., 2008) and extent (Owens et al., 2003); they have shown various degrees of underestimation of disease prevalence (Susin et al., 2005, Vettore et al., 2007, Eke et al., 2010). Therefore, researchers have not reached a consensus on a PMPE protocol to be used for large scale epidemiological studies, leading to the use of different methods to measure periodontitis (Tu et al., 2013, Figueiredo et al., 2013).

To date, it is difficult to compare or combine data across studies to determine the most accurate PMPE protocol. Large variations in methodology and the different case definitions of periodontitis used in the comparisons of PMPE protocols with a FMPE protocol in estimates of periodontitis prevalence, severity and extent have been described. Narrative reviews of PMPE protocols described the strengths and weaknesses of PMPE protocols used for periodontitis surveillance (Beltran-Aguilar et al., 2012, Leroy et al., 2010, Papapanou, 1996). Currently, there is no known comprehensive systematic review of the validity on PMPE protocols across different populations.

Therefore, the aim of this study is to provide an overview on the bias associated with PMPE protocols in relation to the estimation of prevalence, severity or extent values for CAL, PD and REC. The results of this research will set the basis for selection of effective partial recording protocols and periodontal parameters to be considered for periodontal indices.

Material and Methods

Literature Search

A literature search was performed using the following databases: Ovid Medline, PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Exerpta Medica database (EMBASE) and Cochrane database (last search April 2012). A manual search of the references section of the included studies was also conducted. Search strategies for each database can be found in Appendix A. Search terms used were: "periodontitis", "periodontal disease", "partial and full mouth periodontal examination protocol", "prevalence", "severity", and "extent" limited from 1946 to 2012, human studies, and English-language articles.

Inclusion/exclusion criteria

We included original articles which reported results from FMPE and PMPE protocols, or the comparison between them. We excluded studies that did not compare PMPE with FMPE

protocols or studies reporting low prevalence of periodontitis. A FMPE protocol is defined as the examination of all teeth circumferentially (Diamanti-Kipioti et al., 1993) or at mesiobuccal-midbuccal-distobuccal-mesiolingual-midlingual-distolingual (MB-B-DB-ML-L-DL) tooth surfaces (Eke et al., 2010).

In this review, one common threshold for CAL, PD and REC was selected that enabled comparison of PMPE protocols across studies. The World Health Organization (Oral Health Survey-Basic Methods) defined a periodontal pocket as PD ≥ 4 mm and attachment loss related to periodontitis as CAL ≥ 4 mm (World Health Organization, 1997). In addition, CAL and PD ≥ 4 mm and REC ≥ 3 mm were the most commonly used measurements amongst the various thresholds in the included studies. Therefore, we used CAL and PD ≥ 4mm and REC ≥ 3 mm as our thresholds to assess bias associated with the use of PMPEs.

Data collection and synthesis

A data extraction form was created and pilot-tested on five randomly-selected studies. The refined form was used to extract the following data from the studies: author(s) names, publication year, country of study population, study design, study population, sample size, age range, prevalence, severity, extent.

Prevalence is defined as the percent of subjects who have at least one site with the given condition (e.g. CAL ≥ 4mm) (Susin et al., 2005). Severity is defined as the mean CAL, mean PD, and mean REC (Kingman et al., 2008). Extent is defined as the percent of sites with CAL or PD ≥ 4mm or REC ≥ 3mm.

We evaluated PMPE protocols based on sensitivity and relative bias. Sensitivity was defined as the ratio between PMPE protocol prevalence relative to FMPE protocol prevalence (Susin et al., 2005)(Fig. 1). Sensitivity was used to evaluate the effectiveness of a PMPE protocol in estimates of periodontitis prevalence. The specificity of all PMPE protocols was 100% since a PMPE protocol will always find non-disease when FMPE protocol detects non-disease (Kingman and Albandar, 2002). Therefore, the choice of an accurate PMPE protocol depends on the comparison of the different sensitivities. A PMPE protocol with a sensitivity of ≥ 80% was considered to have an acceptable performance (Nelson et al., 2001).

Relative bias was defined as the ratio of difference between the PMPE protocol severity or extent and the FMPE protocol severity or extent relative to the FMPE protocol severity or extent (Kingman et al., 2008)(Fig. 1). Relative bias was used to evaluate a PMPE protocol in estimating severity and extent of periodontitis as compared to the FMPE. A negative relative bias meant underestimation and a positive relative bias meant overestimation. Sensitivities and relative biases were either obtained directly from the included studies, or calculated (according to the definitions) from extracted periodontitis prevalence, severity and extent determined by the FMPE and PMPE protocols in the included studies. An effective PMPE protocol should produce high sensitivity for estimates on disease prevalence and small relative bias for the severity and extent estimates.

Results

Characteristics of the twelve studies included in this review

The database and manual searches yielded 282 citations. Twelve articles met the inclusion criteria (Fig. 2). We excluded 172 duplicate studies, 77 studies which were not relevant to the review, one study in a foreign language, one expert opinion article, four studies comparing PMPE protocols with other PMPE protocols which examined all teeth at two (Hunt and Fann, 1991), three (Thomson and Williams, 2002), or four (Agerholm and Ashley, 1996, Kingman et al., 1988) probing sites per tooth, one study due to low

prevalence of periodontitis (Peres et al., 2012) as its very low prevalence of periodontitis in population (3%) might significantly decrease sensitivity (Kingman et al., 1988), and 14 studies which compared PMPE with FMPE protocols using various thresholds other than CAL and PD ≥ 4 and REC ≥ 3mm (Eke et al., 2010, Diamanti-Kipioti et al., 1993, Downer, 1972, Hunt, 1987, Eaton et al., 2001, Aucott and Ashley, 1986, Fleiss et al., 1987, Mills et al., 1975, Gettinger et al., 1983, Ainamo and Ainamo, 1985, Miller et al., 1990, Rams et al., 1993, Papapanou et al., 1993, Bassani et al., 2006). All the included studies were cross-sectional in design, reporting a total of 32 unique PMPE protocols (Appendix B). These studies assessed PMPE protocols over 25 years, mostly in the US and Brazil (Table 1). The most studied populations were university dental patients and general populations. Sample sizes ranged from 75 to 6,793 subjects, covering wide age ranges.

Risk of bias

We excluded Bassani et al. (2006) as the study applied different case definitions for FMPE and PMPE, making it difficult to compare. We excluded Peres et al. (2012) due to the low prevalence of periodontitis related to the participant's young age; studies by Diamanti-Kipioti et al. (1993) and Papapanou et al. (1993) were also excluded as they selected the maximum CAL of MB or ML sites of teeth # 3,8,11,20,25,27 and maximum CAL of DB or DL in teeth # 3,13,21,27. Depending on the severity of CAL on each site, measurements for MB or ML and DB or DL are recorded, which do not necessarily reflect the periodontal status of the individual.

Frequency of PMPE protocols in the included studies

PMPE protocols were characterized by three elements: quadrant, teeth and probing location per tooth. The most frequently used PMPE protocol examined the six Ramfjord teeth with the periodontal measurements taken at the MB-B-DB-ML-L-DL sites of the teeth. The NHANES III and IV protocols held the second and third positions, followed by the half-mouth six sites protocol. The NHANES III protocol examined all teeth (excluding third molars) in two randomly selected quadrants (one upper and one lower) at two fixed sites per tooth (MB-B) (Table 2).

Researchers used various statistical methods to compare the PMPEs with the FMPE protocol such as percent of subjects with different thresholds of CAL, PD, REC (Susin et al., 2005); mean CAL, PD, or REC (Owens et al., 2003); and percent of tooth surfaces or sites with different thresholds of CAL, PD, and REC (Borges-Yanez et al., 2004). All studies employed CAL or PD with only two studies also including REC (Owens et al., 2003, Dowsett et al., 2002).

Validity of PMPE protocols

Among the 32 reviewed PMPE protocols, we found a large variation in sensitivity for prevalence estimates of periodontitis. Six PMPE protocols had sensitivities ≥ 80% (Table 3), five had sensitivities ranging from 57%–96% (Table 4), with the remainder of protocols measuring sensitivities < 80%. A higher sensitivity was consistently found in the PMPE protocols that examined all teeth as compared to PMPE protocols which examined fewer teeth. Relative biases of six PMPE protocols are shown in Table 3. For all of the PMPE protocols, the relative biases were calculated as ≤ 0.05 in absolute value for severity and extent estimates of periodontitis (Table 3).

Tables 3 and 4 showed that the relative biases of the PMPE protocols in estimates of periodontitis severity (mean CAL or PD) were small and slightly varied by the different PMPE protocols. The association between relative biases for severity estimates and the increased number of probing sites was not clear. Relative biases < 0.05 in absolute value

were produced by 84-probing sites PMPE protocols (half mouth six-sites, full mouth MB-B-DB and MB-B-DL protocols) as shown in Table 3 and 36-probing sites Ramfjord protocol; while those protocols measuring relative biases of < 0.12 were produced by the 28-probing sites NHANES III protocol (Table 4). The highest relative bias (0.15) was found between the FMPE and the CPITN six-sites protocols. There were few comparisons between the PMPEs and FMPE protocols for extent estimates. The half-mouth six-sites protocol provided the lowest relative bias for extent estimates (0.003) while the CPITN six-sites protocol performance was questioned due to the high relative bias of 0.37.

Regarding REC, two PMPE protocols were compared with FMPE protocols for prevalence estimates of REC 3 mm. Only a diagonal protocol which examined all teeth at quadrants 1 and 3, or quadrants 2 and 4, at six sites, had sensitivity estimates calculated at 85%. The Ramfjord protocol had a sensitivity of < 80% (Dowsett et al., 2002). Mean REC was used for six comparisons between the PMPE and FMPE protocols. The PMPE protocol which examined all teeth on quadrants 1 and 4 and diagonal six-sites protocol had relative biases of zero while the other listed PMPE protocols had relative bias from 0.09 to 0.4 in absolute values (Owens et al., 2003). The diagonal protocol provided a relative bias of 0.037 for the estimates of extent in REC 3 mm while the Ramfjord protocol provided a relative bias 0.148 (Dowsett et al., 2002).

Sensitivity and number of probing sites

The scatter plots on Fig. 3 indicate a linear relationship between the number of probing sites and sensitivities of PMPE protocols with regard to the estimates of prevalence of individuals with CAL or PD 4 mm. The sensitivity of a PMPE protocol for prevalence estimate increases with the increasing number of probing sites. Correlation coefficients (r) for the CAL and PD plots were 0.71 and 0.76 respectively. Five studies provided 14 PMPE protocols for the CAL plot (Susin et al., 2005, Kingman and Albandar, 2002, Dowsett et al., 2002); and 10 PMPE protocols for the PD plot (Benigeri et al., 2000, Baelum et al., 1993, Kingman and Albandar, 2002, Dowsett et al., 2002). The prevalence of CAL or PD 4 mm as determined by the FMPE protocols ranged from 30% to 100%. These plots indicated that a PMPE protocol should examine at least 49 sites for CAL and 33 sites for PD to produce a satisfactory sensitivity of 80%. Factors that can have an impact on the sensitivity data and affect the linear relationship include: location of tooth/teeth being examined, the disease level in the population, and the case definition of periodontitis (Eke et al., 2012, Kingman et al., 1988).

Discussion

This study identified three potential PMPE protocols that approximated to a FMPE protocol for prevalence, severity and extent estimates of periodontitis: 1) half mouth six-sites, 2) diagonal quadrants (1 and 3, or 2 and 4) six-sites and 3) full mouth MB-B-DB. Full mouth and half mouth MB-B-DL protocols performed well for estimates of prevalence and severity however their performance in estimating periodontitis extent is still to be elucidated. In addition, this study also found a linear relationship between sensitivity and number of probing sites measured.

Application of five PMPE protocols (half mouth six-sites, diagonal quadrants six-sites, full mouth MB-B-DB, full mouth MB-B-DL, and half mouth MB-B-DL) can reduce the examination time and provide an accurate estimate of periodontitis prevalence, severity and extent. The four PMPE protocols which probe 84 sites (Table 3) can reduce exam time by half. Examining time will be further reduced with the half mouth MB-B-DL PMPE protocol which probes 42 sites only. This reduction in examination time is critical to avoid deleterious effect on the study (Owens et al., 2003).

Validity of PMPE protocols

Aside the 4 mm CAL and PD threshold analyses shown in this systematic review, we wanted to further expand our discussion to studies which used higher threshold values. Studies using a threshold of 6mm on CAL or PD provide additional data which support our findings (Susin et al., 2005, Kingman and Albandar, 2002, Dowsett et al., 2002, Baelum et al., 1993, Benigeri et al., 2000). The half mouth six-site and full mouth MB-B-DB protocols performed well for severe periodontal thresholds. The half mouth six-site protocol provided a sensitivity of   80% in prevalence estimates for subjects with CAL   6 mm (Susin et al., 2005) and of 74.8% in prevalence estimates for subjects with PD   6 mm (Benigeri et al., 2000). The full mouth MB-B-DB and full mouth MB-B-DL protocols provided a sensitivity of   80% for CAL   6 mm (Susin et al., 2005, Kingman and Albandar, 2002). The full mouth MB-B-DB protocol also provided a sensitivity of   80% for PD   6 mm (Kingman and Albandar, 2002). The other PMPE protocols in Table 3 performed poorly as compared to the half mouth six-site and full mouth MB-B-DB protocols for prevalence estimates of CAL and PD   6 mm (Dowsett et al., 2002, Baelum et al., 1993, Susin et al., 2005).

We omitted four studies that compared partial mouth protocols with full mouth 2, 3 or 4 sites PMPE protocols; since the PMPE protocol with less than six sites already underestimates the FMPE, and should not be considered equal to FMPE protocol. We abandoned an additional 14 studies which used various thresholds other than CAL and PD   4 and REC   3mm. Among these 14 studies, only one study (Eke et al., 2010) showed that half mouth six-sites protocol provided a sensitivity of 60% for estimates of periodontitis prevalence according to the CDC/AAP case definition. Two additional publications by Miller et al. (1990) and Ainamo et al. (1985) showed that the CPITN protocol that measures the teeth circumferentially had high sensitivity for the prevalence estimates. The 11 remaining dismissed articles were not found to be contributory to our systematic review as they do not reach a consensus on PMPEs performance.

Four previous narrative reviews (Papapanou, 1996, Leroy et al., 2010, Dhingra and Vandana, 2011, Beltran-Aguilar et al., 2012) did not reach a consensus on an optimal PMPE protocol for a population-based surveillance of periodontitis; our results corroborate these findings. The present study found that the PMPE protocol which used the index teeth from the CPITN index provided sensitivities of   70% for prevalence estimates of PD   4 mm. However, the CPITN protocol provided low sensitivity for prevalence estimates of PD   6 mm (Baelum et al., 1993) and large relative biases for the estimates of periodontitis extent (Table 4). A plausible explanation is that the CPITN is a maximum measure index that does not consider extent of periodontal disease and only classifies a subject according to the maximum measurement. Reviews by Beltran-Aguilar et al. (2012) and Papapanou (1996) of the NHANES protocols indicated an underestimation of the disease prevalence; our review found similar results. The PMPE protocol using the Ramfjord teeth was the most frequently assessed protocol among the selected studies for this systematic review. Although the Ramfjord protocol provided high sensitivity for estimating prevalence of CAL   4 mm (Kingman and Albandar, 2002) and small relative bias for estimating periodontitis severity (Kingman et al., 2008), this PMPE protocol provided low sensitivity for larger CAL thresholds (Kingman and Albandar, 2002). Therefore, it failed to represent the full dentition for a population-based surveillance.

Although the half mouth six-sites and full mouth MB-B-DB protocols performed well for severe periodontal thresholds (CAL or PD   6 mm), their performances according to the case definitions of periodontitis suggested by the CDC/AAP (Eke et al., 2012) or the European Federation of Periodontology (EFP) (Tonetti and Claffey, 2005) remain to be elucidated. The sensitivity of a PMPE protocol in estimates of periodontitis prevalence relies on the disease level in the population (Kingman et al., 1988). The periodontal disease level

is determined by the case definitions of periodontitis used in that particular study. It is important to mention that we did not use case definitions of periodontitis proposed by the CDC/AAP (Eke et al., 2012) or EFP (Tonetti and Claffey, 2005) as all of the studies included in this systematic review did not use these case definitions.

Sensitivity and number of probing sites

This review showed that the number of probing sites was positively associated with the sensitivity with high correlation coefficients (0.71 for CAL and 0.76 for PD), whereas there was no clear evidence of association between probing number and relative bias for severity and extent estimate. These results are in agreement with other studies (Susin et al., 2005, Kingman and Albandar, 2002, Beck et al., 2006). Kingman et al. (2008) indicated that full mouth based PMPE protocols had similar biases of severity estimates as random half-mouth based PMPE protocols. The thirty six-sites Ramfjord protocol produced the lowest biases of severity estimates. Vettore et al. (2007) found that 84-site-based PMPE protocols and 42-sites-based PMPE protocols had similar low biases while a 60-sites-based PMPE protocol produced a large bias for extent estimates.

More importantly, our scatter plots initially propose a minimum number of probing sites that a PMPE protocol should include to accurately reflect the periodontal status of a population. However, these results should be interpreted with caution since additional factors may impact the sensitivity of a PMPE protocol for estimating disease prevalence. The tooth location and probing sites crucially determine bias for prevalence, severity and extent estimates of periodontitis (Susin et al., 2005, Kingman et al., 2008). Additional evidence in Table 3 demonstrated that the 84-sites PMPE protocols provided less bias estimates as compared to 28-sites NHANES III and 42-sites NHANES IV protocols. These results enable us to hypothesize that there could be an acceptable PMPE protocol in the range between 42 to 84 sites.

The advantage of this systematic review is that we evaluate performance of the PMPE protocols at a fixed periodontal threshold of CAL or PD ≥ 4 mm or REC ≥ 3 mm which allow us to compare large quantities of studies regardless on the variation in methods used by different authors. The limitation of this study is that our findings for thresholds CAL or PD ≥ 4 mm cannot be generalized to severe periodontitis or to other cases which used definitions combining both, CAL and PD. Due to the extensive variations between PMPE protocols such as periodontal parameters, case definitions and statistical analyses, which can potentially impact their comparison, further research is needed to evaluate the five potential PMPE protocols identified in this review in accordance to a universally accepted case definition for the estimates of prevalence, severity and extent of periodontitis.

Conclusion

A low estimate bias PMPE protocol is acceptable for a population-based survey to assess periodontitis. Our systematic review of studies published between 1946 and 2012 found that three PMPE protocols (half mouth six-sites; diagonal quadrants six-sites; and full mouth MB-B-DB) were effective in estimating prevalence, mean, and extent of periodontitis, while two other PMPE protocols (full mouth and half mouth MB-B-DL) were identified to be effective in estimating prevalence and severity. All these PMPE protocols need to be further assessed for accurate estimates of periodontitis in the general population using a universally accepted case definition.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Clinical Relevance

Scientific Rationale for the study

Results from clinical trials rely on participant screening and accurate periodontal diagnosis. PMPE protocols represent a tool to screen populations; however, the results are often inconclusive due to suboptimal protocol performance. **Principal Findings:** Half mouth six-sites and full-mouth MB-B-DB protocols produced sensitivities 85% for prevalence estimate and relative biases 0.05 in absolute values for severity and extent estimates. **Practical Implications:** Half mouth six-sites and full-mouth MB-B-DB protocols are suggested for large population based clinical trials due to their high sensitivity for prevalence estimates and small bias for severity and extent estimates.

$$\text{Sensitivity} = \frac{\text{Prevalence}_{\text{PMPE}}}{\text{Prevalence}_{\text{FMPE}}}$$

$$\text{Relative bias} = \frac{\text{Severity}_{\text{PMPE}} - \text{Severity}_{\text{FMPE}}}{\text{Severity}_{\text{FMPE}}}$$

$$\text{Relative bias} = \frac{\text{Extent}_{\text{PMPE}} - \text{Extent}_{\text{FMPE}}}{\text{Extent}_{\text{FMPE}}}$$

Figure 1.
Calculation of the prevalence, severity, extent and relative bias.
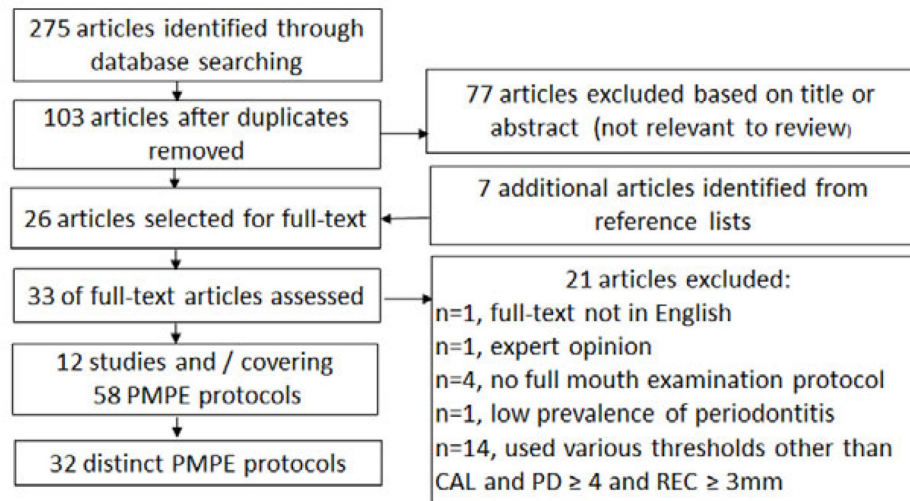
Figure 2.
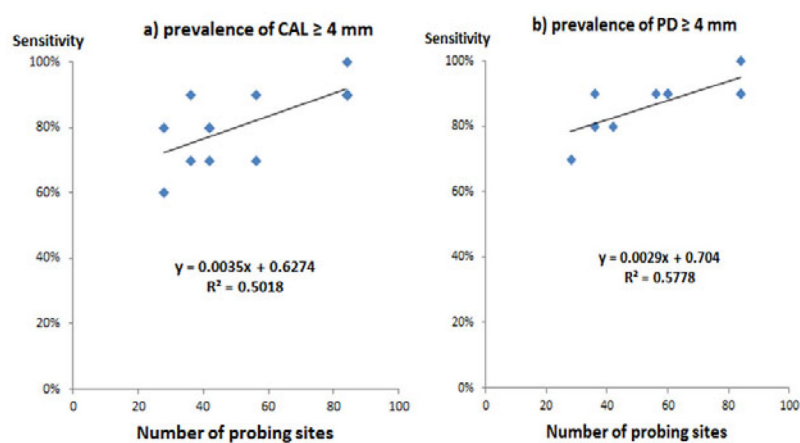Flowchart of study selection process for review.

Figure 3.
Scatter plots of the number of probing sites versus sensitivity of prevalence estimates for PD/CAL   4 mm for different PMPE protocols.

Table 1

Characteristics of the 12 studies included in this review. Studies were conducted between 1988 and 2012

Reference	Country of study population	Study population	Sample size	Age range (years)
Kingman et al. (2008)	Brazil	General population	1,437	14–103
Vettore et al. (2007)	Brazil	University dental patients & pregnant women in public maternity clinics	156	30–67
Beck et al. (2006)	United States	Residents of four US communities	6,793	52–74
Susin et al. (2005)	Brazil	General population	1,460	14–103
Munghamba et al. (2004)	Tanzania	University dental patients	192	15–77
Borges-Yanes et al. (2004)	Mexico	University dental patients	712	20
Owen et al. (2003)	United States	University dental patients	92	23–72
Kingman et al. (2002)	United States	19–23 year old 13–17 adult year old children cohort	266	19–23
Dowsett et al. (2002)	Guatemala	Indigenous population	292	18–78
Benigeri et al. (2000)	Canada	35–44 year old adults	2,110	35–44
Baelum et al. (1993)	Kenya	Rural population	1,131	15–65
Silness et al. (1988)	Norway	Adolescents at University dental clinic	75	15

CS: cross-sectional study

Table 2

Overview on most frequently used PMPEs among the 32 ones considered for this review.

PMPEs	Selected teeth Quadrant	Number of teeth	Probing sites
Ramfjord	#3,8,12,19,24,28 Selected teeth	6#3,8,12,19,24,28	MB-B-DB-ML-L-DL[c]
NHANES IV	Half mouth[a]	14	MB-B-DB
NHANES III	Half mouth[a]	14	MB, B
Half mouth 6	Half mouth[a]	14	MB-B-DB-ML-L-DL
Full mouth 3a	Full mouth	28	MB-B-DB
CPITN 6	#2,3,8,14,15, 18,19,24,30,31 Selected teeth	10#2,3,8,14,15, 18,19,24,30,31	MB-B-DB-ML-L-DL
Full mouth 2	Full mouth	28	MB-B
CPITN C	#2,3,8,14,15, 18,19,24,30,31 Selected teeth	10#2,3,8,14,15, 18,19,24,30,31	Circumferential
Half mouth 3	Half mouth[a]	14	MB-B-DL
Full mouth 3b	Full mouth	28	MB-B-DL
Diagonal 6	Diagonal quadrants[b]	14	MB-B-DB-ML-L-DL

[a]Two randomly selected quadrants (1 upper and 1 lower);

[b]quadrants 1 and 3 or 2 and 4. Quadrants 1 and 3 are the upper right and lower left, while quadrants 2 and 4 are the upper left and lower right;

[c]MB-mesiobuccal, B-midbuccal, DB-distobuccal, ML-mesiolingual, L-midlingual, DL-distolingual

Table 3

PMPE protocols with sensitivity ≥ 80% for estimates of periodontitis prevalence and their relative biases in estimating severity and extent.

PMPEs	Number of probing sites	Reference	Sensitivity[*] (%)		Relative bias – Severity[**] (%)		Relative bias – Extent[***] (%)	
			CAL	PD	CAL	PD	CAL	PD
Half mouth 6	84	Susin et al., 2005	92					
		Benigeri et al., 2000		86				
		Kingman et al., 2008			0.009	0.001		
		Vettore et al., 2007			0	0	0.001	−0.003
Diagonal 6	84	Dowsett et al., 2002	98	98	0.01	0	0.02.0	0.01.7
		Owen et al., 2003			−0.006	−0.004		
Full mouth 3a	84	Susin et al., 2005	92					
		Kingman et al., 2002	85	91	0.009	0.04.5		
		Kingman et al., 2008			−0.04.6	−0.04.9		
		Vettore et al., 2007			−0.01	−0.01.5	−0.02.2	−0.05.0
Full mouth 3b	84	Susin et al., 2005	94					
		Kingman et al., 2008			−0.008	−0.01.3		
CPITN C	n/a	Baelum et al., 1993		85				
Half mouth 3	42	Susin et al., 2005	83					
		Kingman et al., 2008			0.004	−0.01.3		

[*] Sensitivity was determined for prevalence estimates of CAL/PD ≥ 4mm

[**] Mean CAL/PD

[***] Percentage of sites with CAL/PD ≥ 4mm

Table 4

PMPE protocols with sensitivities in the range from 57–96% for estimates of periodontitis prevalence and their associated relative biases for estimates of severity and extent.

| PMPEs | Number of probing sites | Reference | Sensitivity (%) | | Relative bias – Severity* | | Relative bias – Extent** | |
			CAL	PD	CAL	PD	CAL	PD
CPITN 6	60	Benigeri et al., 2000		88				
		Kingman et al., 2002		96				
		Vettore et al., 2007			0.148	0.127	0.317	0.374
		Silness et al., 1988				0.105		
Full mouth 2	56	Susin et al., 2005	86					
		Kingman et al., 2002	66	85	0.009	−0.035		
		Kingman et al., 2008			−0.035	−0.074		
NHANES IV	42	Susin et al., 2005	80					
		Kingman et al., 2002	66	85	−0.09	0.05		
		Kingman et al., 2008			−0.034	−0.048		
		Vettore et al., 2007			−0.01	−0.012	−0.007	−0.029
		Beck et al., 2006			−0.024	−0.054		
Ramfjord	36	Dowsett et al., 2002	92	90	0.01	−0.014	0.016	−0.06
		Kingman et al., 2002	68	77	0.043	0.01		
		Kingman et al., 2008			0.028	−0.017		
		Beck et al., 2006			0.003	−0.009		
		Munghamba et al., 2004				0		
		Owen et al., 2003			0.036	−0.025		
NHANES III	28	Susin et al., 2005	75	73				
		Kingman et al., 2002	57		−0.09	−0.03		
		Kingman et al., 2008			−0.023	−0.072		
		Beck et al., 2006			−0.032	−0.116		

Negative and positive relative bias means under/overestimation of FMPE estimates