Partial-mouth periodontal examination protocol for estimating periodontitis extent and severity in a US population

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Abstract

We have previously demonstrated that half-mouth four-site periodontal examination protocol performed well in estimating periodontitis prevalence. This study aimed to assess biases associated with this same protocol in estimating periodontitis extent and severity in a United States population. Periodontitis extent as determined by percentage of sites with clinical attachment loss (CAL) ≥3, and ≥5 mm and severity as determined by mean CAL were calculated for full-mouth examination and half-mouth four-site protocol based on 3734 adults sampled from the National Health and Nutrition Examination Survey 2009–2010. Probing depth was excluded because of low data reliability. The comparison between full-mouth and half-mouth assessments was based on bias, relative bias, Wilcoxon signed-rank test, and intra-class correlation coefficient (ICC). For full-mouth examination, periodontitis extent was 21.2% for CAL ≥3 mm and 6.9% for CAL ≥5 mm; periodontitis severity (mean CAL) was 1.73 mm. Half-mouth four-site protocol provided bias −1.2% and relative bias −5.7% for extent (CAL ≥3 mm). Corresponding numbers were −0.3% and 4.3% for extent (CAL ≥5 mm), −0.05 mm and −2.9% for severity. Although the difference between full-mouth and half-mouth assessments was statistically significant, ICCs between them were ≥0.96 for extent (CAL ≥3, 5 mm), and severity (mean CAL). Half-mouth four-site protocol performed well in estimating periodontitis extent and severity based on CAL. Therefore, this protocol should be considered for periodontitis surveillance.

Introduction

Periodontitis is one of the major causes of tooth loss and has been associated with the presence of systemic diseases (Linden et al., 2013). However, actual estimates of periodontitis are still unclear because of differences in data acquisition between populations. There have been about ten national or regional oral health surveys using various periodontal examination protocols, measurement techniques, and case definitions (Dye, 2012). Some surveys used full-mouth periodontal examination at six sites per tooth (FMPE) (Aimetti et al., 2015; Eke et al., 2015; Haas et al., 2015), while others used partial-mouth examination at various sites (PMPE) (Do et al., 2003; Bourgeois et al., 2007; Lee et al., 2013). To overcome these limitations, the Joint EU/USA Periodontal Epidemiology Working Group suggested standards for reporting chronic periodontitis prevalence and severity in epidemiologic studies (Holtfreter et al., 2015). According to these standards, FMPE protocol is the gold standard, but a PMPE protocol could be used if financial and time constraints were found; PMPE protocol by definition is the clinical measurement of representative sets of teeth or probing sites (Kingman and Albandar, 2002).

The group also recommended that the estimates of periodontitis prevalence, extent, and severity be reported. Prevalence indicates how widespread periodontitis is; however, it is not sufficient to provide a meaningful comparison of periodontitis between populations as it did not reflect the extent (i.e., the percentage of sites affected at a given level of severity) and the severity of the disease (i.e., mean values computed over all periodontally assessed sites) (Holtfreter et al., 2015). Therefore, a PMPE protocol should be assessed for
periodontitis prevalence, extent, and severity simultaneously in the same population.

Partial-mouth examination at various sites protocols have been used since 1960s (Beltran-Aguilar et al., 2012). While many studies reported the performance of PMPE protocols for periodontitis prevalence, few studies evaluated PMPE protocols for periodontitis extent and severity (Tran et al., 2013). Most studies did not assess PMPE protocols for periodontitis prevalence, extent and severity at the same time in the same population. As the accuracy of a PMPE protocol might be associated with the demographic characteristics and disease level of the population of interest, it has been difficult to determine the most accurate PMPE protocols by comparing data across these studies (Kingman et al., 2008; Chu and Ouyang, 2015). Researchers have shown that some of the most used protocols for the diagnosis of periodontitis have inherent flaws either grossly underestimating the prevalence of the disease or providing inaccurate estimates of extent or severity (Susin et al., 2005; Vettore et al., 2007; Kingman et al., 2008; Eke et al., 2010; Leroy et al., 2010).

A recent study found that half-mouth four-site protocol provided limited bias for the estimate of periodontitis prevalence in a representative sample of the US adult population by lowering the thresholds of CAL and PD in a ‘half-reduced CDC/AAP’ case definition for the PMPE protocol while using the standard CDC/AAP case definition for the gold-standard full-mouth exam (Tran et al., 2014). This protocol examines four interproximal sites (mesiobuccal, distobuccal, mesiolingual, and distolingual) per tooth on one random upper quadrant and one random lower quadrant. There has been only one study assessing this protocol for periodontitis extent and severity in a small sample of workers with chronic periodontitis in China (Chu and Ouyang, 2015). Hence, the aim of the present study was to determine whether half-mouth four-site protocol can substitute for full-mouth assessment of periodontitis extent and severity in a representative sample of US adult population (NHANES 2009–2010).

### Materials and Methods

This cross-sectional study assessed half-mouth four-site protocol using existing data from the National Health and Nutrition Examination Survey (NHANES) 2009–2010 (CDC, 2013). The NHANES included a representative sample of the US population of which 5037 adults aged 30 years and older were eligible for the oral health examination. From the original dataset, we applied subject exclusion criteria as shown in Fig. 1. Subjects were excluded if randomly selected quadrants were edentulous.

Calibrated dental hygienists examined NHANES subjects using Hu-Friedy PCP-2 (Dye, 2012; Eke et al., 2015; Haas et al., 2015) periodontal probe (Hu-Friedy, Chicago, IL, USA) at mobile examination centers. Each measurement of clinical attachment loss (CAL) and probing depth (PD) was rounded to the lowest whole millimeter. CAL and PD measurements were performed at six sites per tooth in all dentition, excluding third molars. Data reliability analysis indicated an acceptable level of data quality for CAL (Dye et al., 2014). Interclass correlation coefficients (ICCs) ranged from 0.69 to 0.90 for CAL at each of the six sites. However, the quality of mid-facial PD measures was poor, with one examiner having ICC of 0.15 for mid-facial PD mean (Dye et al., 2014). Given the half-mouth four-site protocol measures interproximal sites only, inaccurate mid-facial PD measures will significantly bias the results of comparing mean PD between half-mouth four-site and FMPE protocol. Therefore, the present study assessed extent and severity of periodontitis

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**Figure 1.** Selection of NHANES 2009–2010 subjects.

- **Excluded (n= 1,303):**
  - Edentulous (n= 341)
  - Health conditions that required antibiotic prophylaxis before periodontal probing (n= 295)
  - No periodontal examination done (n= 616)
  - Partial periodontal exam (n= 41)
  - Randomly selected quadrants were edentulous (n= 10)

Selected subjects (n= 3,734)
as determined by CAL only to avoid bias due to inaccurate mid-site PD measures.

Other variables included in this study were age, gender, race, education level, and smoking status. They are associated with variation in the periodontitis status (Burt, 2005) which in turn might affect the bias for half-mouth assessment of periodontitis extent and severity (Dowsett et al., 2002; Owens et al., 2003; Kingman et al., 2008). Trained interviewers collected the data using the computer-assisted personal interviewing system.

**Data analyses**

Extent and severity of periodontitis was determined based on (i) percentage of sites with CAL ≥3 mm and ≥5 mm and (ii) mean values computed over all periodontally assessed sites (Holtfreter et al., 2015). PD was not included in the assessment because of low data reliability (Dye et al., 2014). The full-mouth estimates are based on the available sites in the mouth (up to 168 sites) including the mid-facial and the mid-lingual sites. The estimates of extent and severity from FMPE were compared with those from half-mouth assessment using the same collected dataset. The comparison between full-mouth and half-mouth estimates was based on bias, relative bias, Wilcoxon signed-rank test, and intra-class correlation coefficient (ICC). Significant level was set at 0.05. Bias, and relative bias are defined as (Kingman et al., 2008):

\[
\text{Bias} = \frac{\text{meanPMPE} - \text{meanFMPE}}{	ext{meanFMPE}}
\]

\[
\text{Relative bias} = \frac{(\text{meanPMPE} - \text{meanFMPE}) \times 100}{\text{meanFMPE}}
\]

where Mean PMPE = mean CAL or mean percentage of sites with CAL ≥3, 5 mm determined by half-mouth assessment Mean FMPE = mean CAL or mean percentage of sites with CAL ≥3, 5 mm determined by full-mouth assessment.

Half-mouth four-site protocol may over/underestimate periodontitis extent and severity, resulting positive/negative relative bias, respectively. ICC measured absolute agreement between full-mouth and half-mouth estimates of periodontitis extent and severity (Kingman et al., 2008). ICC ≥0.75 indicates excellent reproducibility (Rosner, 2006). Age was categorized into five groups according to proposed standards from the Joint EU/USA Periodontal Epidemiology Work Group (Holtfreter et al., 2015). Comparison between full-mouth and half-mouth assessments was stratified by age, gender, education level, and smoking status. Patients with missing data of any variable previously were not included in the subgroup analysis for that variable. Stata 13 was used for data analysis (StataCorp, 2013).

**Results**

The present study included 3734 subjects whose mean age was 53.4 years (SD = 14.4). Approximately half of subjects were white, male, current smoker, and having some college education or higher. Mean number of teeth was 23 (SD = 6.2), and the range was 1–28 teeth. Periodontitis extent and severity followed a non-normal distribution skewed to the right (Table 1).

Mean periodontitis extent (percentage of sites with CAL ≥3 mm) was 21.2% for FMPE and 20% for half-mouth four-site protocol; corresponding numbers were 6.9% and 6.6% for CAL ≥5 mm (Table 2). Half-mouth four-site protocol underestimated mean percentage of sites with CAL ≥3, and ≥5 mm by 5.7% and 4.3%, respectively. The difference between the two protocols was statistically significant. When stratified by age, gender, education level, and smoking status, half-mouth four-site protocol provided biases of <2% in absolute value for the estimates of mean percentage of sites with CAL ≥3 mm; the associated relative biases were <10%. For CAL ≥5 mm, biases were <0.5%, and relative biases were <15% in absolute value across all strata. Generally, relative bias in absolute value decreased as the severity thresholds or percentage of the sites with CAL ≥3, and ≥5 mm increased.

Regarding periodontitis severity as determined by mean CAL, half-mouth four-site protocol provided nearly identical estimates. Mean CAL for FMPE and half-mouth four-site protocol was 1.73 and 1.68 mm, respectively (Table 3).

### Table 1. Characteristics of National Health and Nutrition Examination Survey sample.

| Characteristics               | Number (%) |
|-------------------------------|------------|
| Age (years)                   |            |
| 30–34                         | 435 (11.7) |
| 35–44                         | 905 (24.2) |
| 45–54                         | 871 (23.3) |
| 55–64                         | 702 (18.8) |
| 65+                           | 821 (22)   |
| Race/ethnic group             |            |
| Mexican American              | 671 (18)   |
| Other Hispanic                | 401 (10.7) |
| Non-Hispanic White            | 1789 (47.9)|
| Non-Hispanic Black            | 671 (18)   |
| Other race-including multi-racial | 202 (5.4) |
| Gender                        |            |
| Male                          | 1867 (50)  |
| Female                        | 1867 (50)  |
| Education level               |            |
| Less than high school         | 1023 (27.5)|
| High school or equivalent     | 815 (21.9) |
| Some college or higher        | 1887 (50.6)|
| Current smoker                |            |
| Yes                           | 727 (43.3) |
| No                            | 953 (56.7) |
Difference between full-mouth and half-mouth assessments of mean CAL was $-0.05$ mm, and associated relative bias was $-2.9\%$. For all strata of age, gender, education level, and smoking status, half-mouth four-site protocol showed biases of $<0.07$ mm and relative biases of $<4\%$ in absolute value.
Interclass correlation coefficients between full-mouth and half-mouth assessments were 0.97 for severity (mean CAL) and extent (CAL ≥3 mm), and 0.96 for extent (CAL ≥5 mm) (Table 4). For all strata, ICCs were ≥0.94 except for the case of CAL ≥5 mm the ICC was 0.84 in age group 30–34. ICCs decreased as the severity thresholds increased.

**Discussion**
This study showed that half-mouth four-site protocol closely approximates FMPE protocol in estimating periodontitis severity as determined by mean CAL, and extent as determined by the percentage of sites with CAL ≥3, and ≥5 mm. Bias and relative bias for half-mouth assessments of extent and severity were small although the difference between half-and full-mouth assessments was statistically significant. Agreement level between full-mouth and half-mouth assessments was high. Taking these results together with good performance in estimating periodontitis prevalence (Tran et al., 2014), we supported the use of half-mouth four-site protocol to describe the prevalence, extent, and severity of periodontitis in a population.

There have been few studies that examined the half-mouth four-site protocol as compared with different PMPE protocols (Owens et al., 2003; Vettore et al., 2007; Kingman et al., 2008; Chu and Ouyang, 2015). As today, there has been only one study which compared half-mouth four-site with FMPE protocol in estimating periodontitis extent and severity in a Chinese population with chronic periodontitis (Chu and Ouyang, 2015). This study reported good accuracy for the extent and severity estimates based on CAL (biases <2%, relative biases <4% in absolute value, and ICCs ≥0.934 for percentage of sites with CAL ≥2, 4, and 6 mm; bias = 0.04 mm, relative bias = 2.1%, and ICC = 0.978 for mean CAL), which supported our results. The study in China was limited to workers who suffered periodontitis and had 16 teeth or more, while our study used a representative sample of the US adult population with or without periodontitis who had 1–28 teeth. Another study on 1437 dentate Brazilian subjects 14- to 103-years old having at least four teeth did not examined half-mouth four-site protocol, but it showed that half-mouth maximum likelihood protocol provided a very small absolute bias of 0.01 mm and relative bias of 0.7% for mean CAL (Kingman et al., 2008). We could extrapolate from this result biases for half-mouth four-site protocol to be smaller for mean CAL because it samples not only maximum likelihood but also other three interproximal sites.

Our study did not include PD in the assessment due to unreliable mid-facial PD measures; Dye et al. reported ICC of 0.15 for mid-facial PD mean (Dye et al., 2014) indicating poor reproducibility (Rosner, 2006) and a large amount of measurement error with mid-facial PD measures. Reasons for measurement bias include inconsistent angulation, probe pressure, and measurement rounding (Dye et al., 2014). The periodontal probes are marked in 2-mm increments, and examiners are trained to round down to the nearest whole millimeter. FMPE protocol uses mid-facial PD measures for the estimates of extent and severity, while the half-mouth four-site protocol does not. Therefore, inaccurate mid-facial PD measures will significantly contribute to the bias of comparison between the two protocols. Low inter-rater reliability could lead to the false conclusions about the hypotheses under study (Hallgren, 2012).

Although we did not incorporate PD in the assessment of the half-mouth four-site protocol, a study in China (Chu and Ouyang, 2015) reported a small absolute bias of 0.37 mm, relative bias of 12.6%, ICC of 0.7 for mean PD, and an excellent reproducibility for periodontitis extent based on PD by the half-mouth four-site protocol (ICCs ≥0.783) according to criteria described by Rosner (Rosner, 2006). We could also infer that the half-mouth four-site protocol provided limited bias for mean PD because Kingman et al. (Kingman et al., 2008) reported very small biases for the half-mouth DB protocol (absolute bias = 0.01 mm, relative bias = 0.2%).

It is possible that PMPE protocols sampling less than 56 sites may also be able to estimate extent and severity with limited bias. Indeed, this is a much easier than estimating prevalence with PMPE protocols. A study showed that seven multi-site PMPE protocols and the Ramfjord PMPE protocol produced small biases in mean PD (−0.17 to 0.04 mm) and mean CAL with relative biases under 8% and 4% in absolute value for mean PD and mean CAL, respectively (Kingman et al., 2008). However, many of these protocols did not

### Table 4. Intra-class correlation coefficients for random half-mouth four-site protocol by selected characteristics.

|                         | Extent (CAL ≥3 mm) | Extent (CAL ≥5 mm) | Severity (CAL) |
|-------------------------|--------------------|--------------------|----------------|
| **Total**               | 0.97               | 0.96               | 0.97           |
| **Age groups (years)**  |                    |                    |                |
| 30–34                   | 0.95               | 0.84               | 0.96           |
| 35–44                   | 0.97               | 0.98               | 0.98           |
| 45–54                   | 0.96               | 0.96               | 0.97           |
| 55–64                   | 0.96               | 0.96               | 0.97           |
| 65+                     | 0.95               | 0.94               | 0.97           |
| **Gender**              |                    |                    |                |
| Male                    | 0.97               | 0.96               | 0.98           |
| Female                  | 0.96               | 0.94               | 0.97           |
| **Education level**     |                    |                    |                |
| Less than high school   | 0.96               | 0.96               | 0.97           |
| High school or equivalent | 0.97           | 0.97               | 0.98           |
| Some college or higher  | 0.96               | 0.94               | 0.97           |
| **Current smoker**      |                    |                    |                |
| Yes                     | 0.97               | 0.97               | 0.98           |
| No                      | 0.96               | 0.95               | 0.97           |
perform well in estimating periodontitis prevalence according to the CDC/AAP case definition (Tran et al., 2013; Tran et al., 2014). The optimal choice of PMPE protocol for periodontitis surveillance should be balanced between its performance in estimating prevalence and extent or severity of periodontitis. The half-mouth four-site protocol provided larger but still small biases for extent and severity compared with PMPE protocols which sample less than 56 sites such as half-mouth MB-B-DL (Chu and Ouyang, 2015). However, it performed better than the half-mouth MB-B-DL in prevalence estimates using the CDC/AAP case definition (Tran et al., 2014). Therefore, the half-mouth four-site protocol would be an optimal choice for periodontitis surveillance.

This study had the advantage of using a large representative sample size of the US adult population with full-mouth periodontal exam to assess the performance of half-mouth four-site protocol. NHANES is an ongoing representative survey which had good data quality assurance through consistent methodology and calibration of examiners (Dye et al., 2014). To the best of our knowledge, the present study was the first to evaluate half-mouth four-site protocol in a large national sample. While a large representative sample of the US adult population was used, the statistical analysis did not take into account the NHANES sampling design including sampling weights. Therefore, our results could not be generalized to the US population and were meant only to demonstrate that the PMPE protocol could be used instead of FMPE. The focus on just CAL rather than also incorporating pocket depths as used in definitions of periodontal diseases is a limitation of this study. As there was a large amount of measurement error with mid-facial PD measures, it would be necessary to reproduce our findings in various populations with reliable CAL and PD measurements.

Conclusion

Our findings showed that the half-mouth four-site protocol performed well in estimates of periodontitis extent and severity based on CAL. Therefore, the protocol should be considered for periodontitis surveillance.

Conflict of Interest

The authors declare no conflict of interest.

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