

Proposing a Novel, Three-level Definition of Periodontitis using Probing Depth, Clinical Attachment Loss and Bleeding on Probing: Analysis of a Rural Chinese Population

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Objective: To propose a novel, three-level (severe, moderate, mild) case definition using probing depth (PD), clinical attachment loss (CAL) and bleeding on probing (BOP) for epidemiologic studies on periodontitis.

Methods: Case definitions (DEF) 1–30 with PD, CAL and BOP were made. Based on data from epidemiologic research in Chengde (Hebei Province, China) in 1992, prevalence of periodontitis by DEF1–30 was calculated and compared with a reference (definitions by Centers for Disease Control and Prevention/American Academy of Periodontology in 2012). Sensitivity, specificity, Youden Index, Cohen's kappa coefficient (CKC) and the area under the receiver operator characteristic curve (AUC) were calculated for the definitions selected.

Results: DEF1 and DEF18 for periodontitis, DEF2, DEF3, DEF19 for moderate and severe periodontitis, and DEF5, DEF13, DEF14, DEF21 and DEF25 for severe periodontitis, which were similar for estimation of periodontitis prevalence compared with the reference, were selected. DEF18 for periodontitis, DEF19 for moderate and severe periodontitis, and DEF5 for severe periodontitis were selected because they showed higher values for the Youden Index, CKC and AUC, and formed a three-level definition.

Conclusion: A novel three-level case classification of periodontitis using three parameters of PD, CAL and BOP was proposed. The estimated periodontitis prevalence according to the novel proposed definition is close to the prevalence according to the CDC/AAP definition.

Key words: bleeding on probing, clinical attachment loss, definition, periodontitis, probing depth

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Periodontitis is a chronic inflammatory disease caused by bacterial infection of the supporting tissues around the teeth. It leads to deep pockets, attachment loss, bone loss and finally tooth loss. Case definitions of periodontitis among epidemiologic surveys differed¹⁻¹², thereby

hindering comparison of the prevalence of periodontitis^{6-8,13-17}. Different case definitions led to different values for the prevalence of periodontitis even though identical data were analysed¹⁵. Different case definitions also led to different results regarding the association between periodontitis and systemic diseases^{12,13,18}. For example, Manau et al applied 14 definitions of periodontitis to test for associations between periodontal disease and pregnancy outcomes. Six of the 14 case definitions resulted in significant associations with adverse pregnancy outcomes, whereas no significance was found using the other eight case definitions¹⁴. If a standard case definition of periodontitis can be agreed upon and used broadly, this problem would be solved¹⁹.

The Fifth European Workshop on Periodontology proposed definitions of periodontitis²⁰ for use in epidemiologic studies of risk factors. Clinical attachment loss (CAL) was used as the sole indicator. The defini-

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tions were two levels of periodontitis and severe periodontitis. In 2007, the Centers for Disease Control and Prevention (CDC) in partnership with the American Academy of Periodontology (AAP) proposed case definitions of “moderate” periodontitis and “severe” periodontitis for use in population-based surveillance²¹. In 2012, a case definition of mild periodontitis was added. Thus, three-level (severe, moderate, mild) case definitions of periodontitis were created²². The definition was based on the parameters of probing depth (PD) and CAL. The definitions set by the CDC/AAP in 2012 have been used in several recent epidemiologic studies²³⁻²⁵ and accepted preliminarily as a reference^{1,15,26}. It has been suggested that CDC/AAP 2012 definitions could be standardised case definitions for population-based studies of periodontitis^{23, 27}.

The two broadly accepted definitions mentioned above used CAL only or CAL and PD as parameters, but without bleeding on probing (BOP). As “true” periodontitis was widely defined as a plaque-induced inflammatory disease, inflammation was the basic and important symptom. BOP is an important parameter that reflects current periodontal inflammation²⁸, which is the simplest way to assess the current inflammation. PD is defined as the distance from the gingival margin to the base of the pocket. PD provides a useful overall assessment of periodontal pockets. Using PD alone might cause a pseudo-pocket (“gingival pocket”) to be classified as a real periodontal pocket²⁹. CAL is the distance from the cement-enamel junction to the base of the pocket, and reflects accumulative periodontal damage³⁰. Using CAL alone might lead sites of gingival recession by mechanical forces without inflammation to be misclassified as diseased sites³¹. Therefore, using only CAL or CAL and PD without BOP to define periodontitis can lead to overestimation or underestimation of disease.

The two definitions mentioned above used only interproximal sites. However, periodontitis can also occur at buccal sites and lingual sites besides the interproximal sites. Case definitions of periodontitis based only on interproximal sites can misclassify cases and underestimate disease prevalence. When central sites were used, the gingival recession and toothbrush abrasion would influence the accuracy of disease estimation. If BOP was added as a parameter to define periodontitis, this problem will be resolved.

The objective of this study was to propose a novel three-level definition of severe, moderate and mild periodontitis combining the parameters of PD, CAL and BOP in population-based studies. All six sites per tooth were considered.

Materials and methods

The present study was based on epidemiologic data^{32,33} from Chengde (a city in Hebei Province, China) in 1992. Subjects were selected from a village in Chengde. The total population of the village was 2,124. Traditionally, oral hygiene practices in this village were limited. No more than half of the villagers possessed a toothbrush and the closest dental clinic was about 10 km away.

A sample of 486 people between the ages of 15 and 44 years (211 males and 275 females) were enrolled using a stratified randomised sampling method. The inclusion criteria for the subjects were: 15 to 44 years old, good general health, fewer than two missing teeth (excluding third molars) and no previous periodontal treatment. Exclusion criteria were: disagreement with the examinations and inability to participate in the following annual oral examination³². The sample size of the 15 to 24-year-old age group was much greater than other age groups due to the greater possibility of dropout in this younger group³². They were examined by one of four dentists. Two random quadrants (maxillary right and mandibular left, or maxillary left and mandibular right) were selected. PD, CAL and the Modified Bleeding Index (MBI)³⁴ were measured at six sites (mesio-buccal, buccal, disto-buccal, mesio-lingual, lingual, disto-lingual) per tooth. Third molars were excluded. The method for determination of MBI has been described in detail by Suda et al³⁴. Basic analyses of the study data have been published³²⁻³⁵.

Thirty case definitions using three parameters are shown in Table 1. The CDC/AAP definitions proposed in 2012²² were used as reference standards: “severe periodontitis” referred to ≥ 2 interproximal sites with $CAL \geq 6$ mm (not on the same tooth) and ≥ 1 interproximal site with $PD \geq 5$ mm; “moderate periodontitis” referred to ≥ 2 interproximal sites with $CAL \geq 4$ mm (not on the same tooth) or ≥ 2 interproximal sites with $PD \geq 5$ mm (not on the same tooth); “mild periodontitis” referred to ≥ 2 interproximal sites with $CAL \geq 3$ mm and ≥ 2 interproximal sites with ≥ 4 mm PD (not on the same tooth) or 1 site with ≥ 5 mm PD. According to the analysis in the paper²², moderate cases included only moderate cases while removing the severe cases; mild cases include only mild cases while removing the moderate and severe cases. In this article, we described the definitions and analysed the data, and compared the results with that analysed by CDC/AAP definitions²².

Prevalence of the corresponding periodontitis was calculated. Definitions were selected according to the similarity of the prevalence with the reference.

Sensitivity (true positive/(true positive + false negative)), specificity (true negative/(true negative + false positive)), the Youden Index (sensitivity + specificity-1), Cohen’s kappa coefficient (CKC), and the area under the receiver operator characteristic (ROC) curve (AUC) for the prevalence of periodontitis compared with the reference, were estimated. The higher the Youden Index, CKC and the AUC, the better the diagnostic capabilities. For selection, two steps were undertaken. Firstly, the prevalence of periodontitis based on candidate definitions was compared with that of CDC/AAP definitions. The definitions showed that similar results were obtained. Secondly, based on the definitions selected at the first step, definitions with highest values for the Youden Index, CKC, and AUC, when compared with CDC/AAP definitions, were selected.

Results

Prevalence of periodontitis according to CDC/AAP definitions

In the study population, the prevalence of periodontitis was 59.05% by CDC/AAP definitions, with severe periodontitis 12.35%, moderate periodontitis 33.95% and mild periodontitis 12.75% (Table 2). Prevalence of moderate and severe periodontitis was 46.30%.

Prevalence of periodontitis using 30 case definitions

Prevalence of periodontitis using 30 case definitions varied from 7.2% to 65.23% (Fig 1). Prevalence of periodontitis using definition number 1 (DEF1) and DEF18 were 65.23% and 52.26%, respectively. Among the 30 case definitions, DEF1 and DEF18 were the most similar with respect to estimation of the prevalence of periodontitis.

Prevalence of moderate and severe periodontitis using DEF2, DEF3, and DEF19 was 47.33%, 36.01% and 36.21% respectively. When using the reference, they had a similarity of 46.30%.

Prevalence of severe periodontitis using DEF5, DEF13, DEF14, DEF21 and DEF25 was 12.35%, 13.17%, 10.70%, 12.55% and 10.91% respectively. When using the reference, they had a similarity of 12.35%.

The definitions mentioned above that were similar with the reference were selected for their diagnostic valuations (Table 3).

Table 1 Thirty case definitions of periodontitis.

Number	Definition
DEF1	≥ 1 site PD ≥ 4 mm and CAL ≥ 2 mm and BOP (+)
DEF2	≥ 1 site PD ≥ 4 mm and CAL ≥ 3 mm and BOP (+)
DEF3	≥ 1 site PD ≥ 4 mm and CAL ≥ 4 mm and BOP (+)
DEF4	≥ 1 site PD ≥ 4 mm and CAL ≥ 5 mm and BOP (+)
DEF5	≥ 1 site PD ≥ 4 mm and CAL ≥ 6 mm and BOP (+)
DEF6	≥ 1 site PD ≥ 5 mm and CAL ≥ 2 mm and BOP (+)
DEF7	≥ 1 site PD ≥ 5 mm and CAL ≥ 3 mm and BOP (+)
DEF8	≥ 1 site PD ≥ 5 mm and CAL ≥ 4 mm and BOP (+)
DEF9	≥ 1 site PD ≥ 5 mm and CAL ≥ 5 mm and BOP (+)
DEF10	≥ 1 site PD ≥ 5 mm and CAL ≥ 6 mm and BOP (+)
DEF11	≥ 1 site PD ≥ 6 mm and CAL ≥ 2 mm and BOP (+)
DEF12	≥ 1 site PD ≥ 6 mm and CAL ≥ 3 mm and BOP (+)
DEF13	≥ 1 site PD ≥ 6 mm and CAL ≥ 4 mm and BOP (+)
DEF14	≥ 1 site PD ≥ 6 mm and CAL ≥ 5mm and BOP (+)
DEF15	≥ 1 site PD ≥ 6 mm and CAL ≥ 6 mm and BOP (+)
DEF16	≥ 1 site PD ≥ 7 mm and CAL ≥ 4 mm and BOP (+)
DEF17	≥ 1 site PD ≥ 7 mm and CAL ≥ 5 mm and BOP (+)
DEF18	≥ 2 sites PD ≥ 4 mm and CAL ≥ 2 mm and BOP (+)
DEF19	≥ 2 sites PD ≥ 4 mm and CAL ≥ 3 mm and BOP (+)
DEF20	≥ 2 sites PD ≥ 4 mm and CAL ≥ 4 mm and BOP (+)
DEF21	≥ 2 sites PD ≥ 4 mm and CAL ≥ 5 mm and BOP (+)
DEF22	≥ 2 sites PD ≥ 4 mm and CAL ≥ 6 mm and BOP (+)
DEF23	≥ 2 sites PD ≥ 5 mm and CAL ≥ 2 mm and BOP (+)
DEF24	≥ 2 sites PD ≥ 5 mm and CAL ≥ 3 mm and BOP (+)
DEF25	≥ 2 sites PD ≥ 5 mm and CAL ≥ 4mm and BOP (+)
DEF26	≥ 2 sites PD ≥ 5 mm and CAL ≥ 5 mm and BOP (+)
DEF27	≥ 2 sites PD ≥ 5 mm and CAL ≥ 6 mm and BOP (+)
DEF28	≥ 2 sites PD ≥ 6 mm and CAL ≥ 2 mm and BOP (+)
DEF29	≥ 2 sites PD ≥ 6 mm and CAL ≥ 3 mm and BOP (+)
DEF30	≥ 2 sites PD ≥ 6 mm and CAL ≥ 4 mm and BOP (+)

DEF: definition

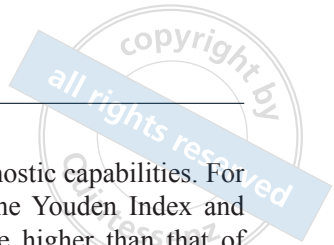


Table 2 Prevalence of periodontitis according to CDC/AAP definitions.

Classification	Number (n)	%
CAC/AAP severe cases	60	12.35
CAC/AAP moderate cases	165	33.95
CAC/AAP mild cases	62	12.75
Total moderate and severe cases	225	46.30
Total periodontitis cases	287	59.05

Diagnostic values in comparison with definitions set by the CDC/AAP

Sensitivity, specificity, the Youden Index, CKC, and the AUC for the prevalence of periodontitis compared with the reference were estimated (Table 3). CKC values were > 0.40 and < 0.75, with moderate agreement. All AUC values were > 0.70, suggesting moderate diagnostic capabilities (Fig 2).

The Youden Index, CKC and AUC of DEF18 were higher than that of DEF1 for the definition of periodontitis, suggesting better diagnostic capabilities of DEF18. For definition of moderate and severe cases, the Youden Index and CKC of DEF3 and DEF19 were higher than that for DEF2. DEF19 presented the highest AUC value

(0.796), suggesting the best diagnostic capabilities. For the definition of severe cases, the Youden Index and CKC of DEF5 and DEF21 were higher than that of DEF13, DEF14 and DEF25. DEF5 presented the highest AUC value (0.857), suggesting the best diagnostic capabilities.

Finally, novel case definitions using three parameters (DEF5, DEF19, DEF18) were proposed: severe periodontitis refers to ≥ 1 site PD ≥ 4 mm, CAL ≥ 6 mm, and BOP (+); moderate periodontitis refers to ≥ 2 sites PD ≥ 4 mm, CAL ≥ 3 mm, and BOP (+); mild periodontitis refers to ≥ 2 sites PD ≥ 4 mm, CAL ≥ 2 mm and BOP (+).

Discussion

Case definitions of periodontitis differed among periodontal epidemiologic surveys and most have employed one or two parameters¹⁻¹². BOP is an important parameter that reflects the current inflammatory status. Using only PD and/or CAL can lead to inaccurate estimation of periodontal diseases^{29,31}.

Using the parameters of PD, CAL and BOP, 30 three-parameter definitions were employed to analyse the data of villagers in Chengde in this current study. By comparing the prevalence of periodontitis with definitions set by the CDC/AAP, three-level (severe, moderate, mild) definitions of periodontitis were eventually selected. We hope these definitions can help researchers make fewer misclassifications in future periodontal epidemiological studies.

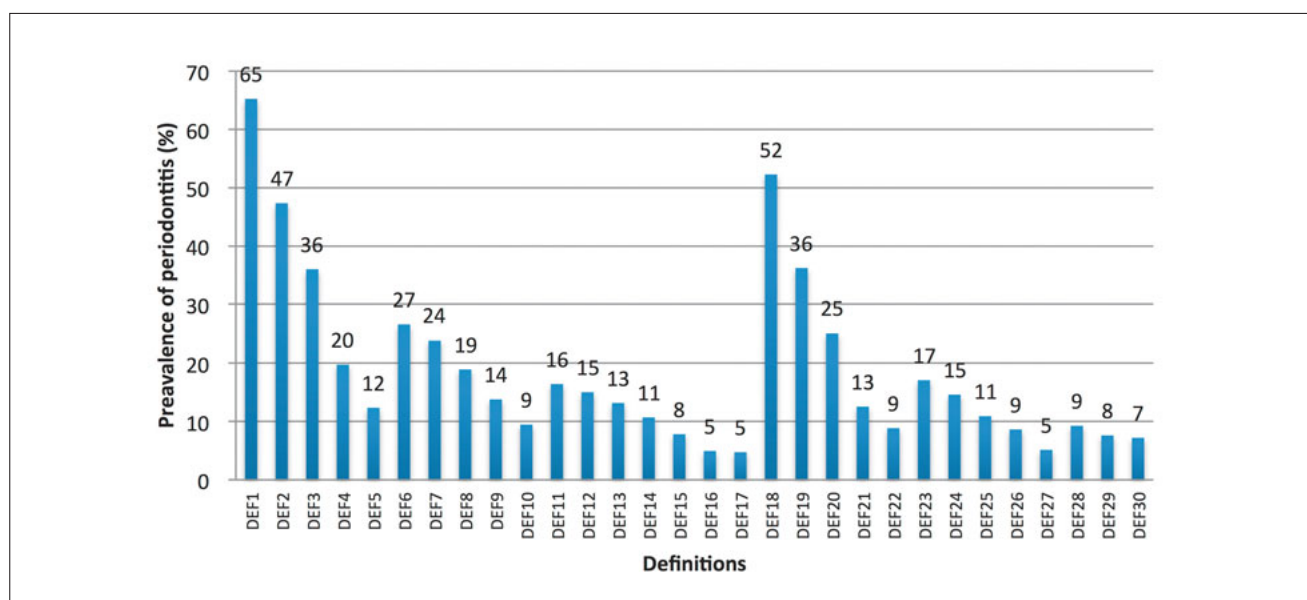


Fig 1 Prevalence of periodontitis using 30 case definitions.

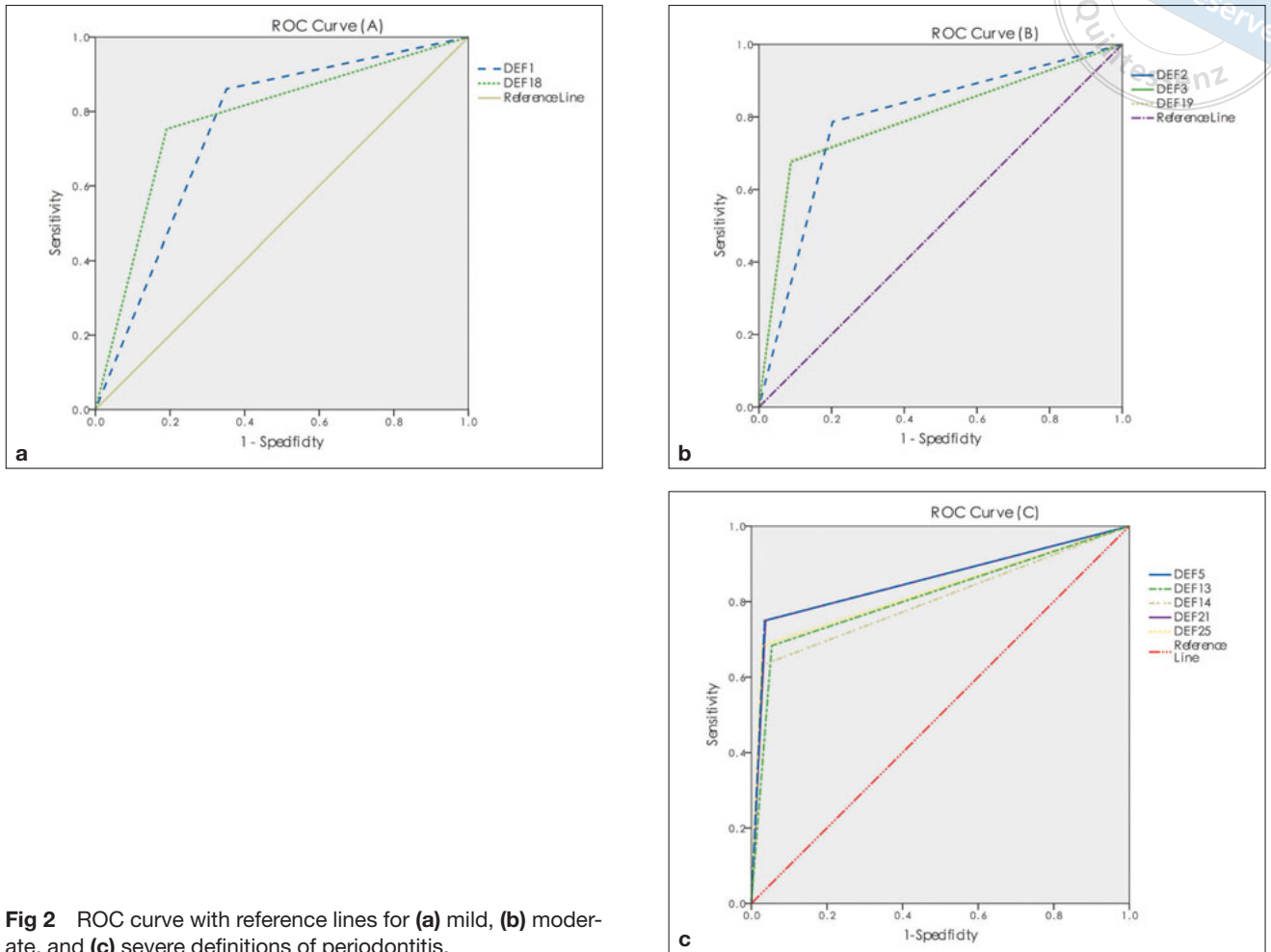


Fig 2 ROC curve with reference lines for (a) mild, (b) moderate, and (c) severe definitions of periodontitis.

Table 3 Diagnostic values of different case definitions compared with the reference (CDC/AAP definitions).

Severity	Number	Prevalence of periodontitis (%)	Sensitivity (95% CI)	Specificity (95% CI)	Youden index (95% CI)	CKC (95% CI)	Δ ROC (95% CI)
Mild/moderate/severe	DEF1	65.23	0.86 (0.82–0.90)	0.64 (0.58–0.71)	0.51 (0.43–0.59)	0.52 (0.44–0.60)	0.754 (0.708–0.801)
	DEF18	52.26	0.75 (0.70–0.80)	0.81 (0.75–0.86)	0.56 (0.49–0.64)	0.55 (0.47–0.62)	0.781 (0.738–0.824)
Moderate/severe	DEF2	47.33	0.79 (0.73–0.84)	0.80 (0.75–0.85)	0.58 (0.51–0.66)	0.58 (0.51–0.66)	0.792 (0.750–0.834)
	DEF3	36.01	0.68 (0.61–0.74)	0.91 (0.88–0.95)	0.59 (0.52–0.66)	0.60 (0.52–0.67)	0.794 (0.751–0.836)
	DEF19	36.21	0.68 (0.62–0.74)	0.91 (0.88–0.95)	0.59 (0.52–0.66)	0.60 (0.53–0.67)	0.796 (0.754–0.838)
Severe	DEF5	12.35	0.75 (0.64–0.86)	0.96 (0.95–0.98)	0.71 (0.60–0.83)	0.71 (0.62–0.81)	0.857 (0.791–0.924)
	DEF13	13.17	0.68 (0.57–0.80)	0.95 (0.92–0.97)	0.63 (0.51–0.75)	0.61 (0.50–0.72)	0.815 (0.743–0.887)
	DEF14	10.70	0.63 (0.51–0.76)	0.97 (0.95–0.98)	0.60 (0.48–0.72)	0.64 (0.52–0.75)	0.800 (0.724–0.876)
	DEF21	12.55	0.75 (0.64–0.86)	0.96 (0.94–0.98)	0.71 (0.60–0.82)	0.71 (0.61–0.81)	0.856 (0.790–0.922)
	DEF25	10.91	0.68 (0.57–0.80)	0.97 (0.96–0.99)	0.66 (0.54–0.77)	0.69 (0.58–0.80)	0.828 (0.755–0.900)

CKC: Cohen's kappa coefficient; ROC: receiver operating characteristic

This is the first time the three-level (severe, moderate, mild) definitions of periodontitis using the parameters of PD, CAL and BOP have been proposed. When reviewing definitions of periodontitis in epidemiologic studies³⁶, we found that PD, CAL and the Gingival Index were applied to a “mild” definition of periodontitis. Alpagot et al¹⁰ defined periodontitis sites as Gingival Index > 0, PD > 3 mm, and CAL ≥ 3 mm. They diagnosed subjects as having periodontitis by this definition based on the most diseased site. However, they did not include moderate periodontitis and severe periodontitis. Other definitions of periodontitis have involved only one or two parameters (PD, CAL, BOP, alveolar bone loss, furcation involvement). Some definitions have involved a combination of PD and CAL, whereas others have involved PD or CAL alone. Alveolar bone loss or furcation involvement have rarely been included^{5,37}.

In our new definitions, BOP was combined with PD and CAL. BOP is an important parameter that reflects current periodontal inflammatory status²⁸. PD provides a useful overall assessment of periodontal pockets. Using PD alone can lead to pseudo-pockets being classified as real periodontal pockets²⁹. CAL reflects accumulative periodontal damage³⁰. Using CAL alone might lead sites of gingival recession by mechanical forces without inflammation to be misclassified as diseased sites³¹. Mechanical forces or successful periodontal treatment causes such recession at no inflammatory sites. To avoid the bias brought about by toothbrush abrasion, some definitions (e.g. CDC/AAP definitions) involve two parameters (PD and CAL) evaluated only at interproximal sites. However, periodontitis can also occur at buccal and lingual sites. Case definitions of periodontitis based only on interproximal sites can lead to misclassification of cases and underestimation of the prevalence of periodontitis²². If the parameter of BOP is added to the definition of periodontitis, the bias brought about by toothbrush abrasion could be avoided to some extent.

In 2010, Leroy et al³⁸ reviewed definitions of periodontitis, and recommended that CAL, PD and BOP should be considered as the three key variables in epidemiologic studies. Using only CAL and/or PD without BOP to define periodontitis can lead to overestimation/underestimation of disease. It is better to consider the three parameters of PD, CAL and BOP while defining periodontitis.

In our new three-level definitions, the definition of each level was selected. DEF5, DEF19 and DEF18 were finally chosen represented the severe, moderate/severe, and total definitions of periodontitis, respectively.

Our proposed definition is simple to use in epidemiologic studies and has an acceptable level of accuracy. If subjects are classified with our proposed definition, there is no need to distinguish between interproximal sites and central sites, which can be helpful in practice. By this definition, BOP is as an additional parameter when compared with the definitions set by the CDC/AAP. However, BOP can be obtained simultaneously with PD without additional procedures.

In the present study, CDC/AAP definitions were used as the reference. Until now, there were no established “gold standard” definitions for periodontitis. In several recent epidemiologic studies²³⁻²⁵, CDC/AAP definitions were used to estimate the prevalence of periodontitis. They have also been used as a reference in several other types of study^{1,15,26}. It has been suggested that the CDC/AAP 2012 definitions could be the standardised case definitions for population-based studies of periodontitis^{23,27}. However, CDC/AAP definitions have two main limitations: (i) they consider only interproximal sites: (ii) they do not consider BOP. These limitations were another reason why we proposed new definitions of periodontitis. Addition of BOP into the definition of periodontitis reflects disease status more accurately than definitions based on two parameters, as well as leading to a lower risk of misclassification.

In this study, the random half-mouth examination of six sites/tooth was used. This was the limitation of the study, for partial protocols may underestimate prevalence and incidence of periodontal diseases³⁹. However, in epidemiological studies, the partial mouth protocols were performed sometimes for conserving time, limiting costs and reducing patient fatigue. Among the partial mouth protocols, the random half-mouth examination of six sites/tooth was reported to provide maximum and accurate information^{40,41}. Another limitation of the present study was that subjects were aged 15 to 44 years. Further studies will be conducted in more patients of a wider age range to assess the validity of our new definitions for use in epidemiologic studies of periodontitis.

Conclusion

A novel, three-level definition of periodontitis using PD, CAL and BOP is proposed. The criteria for periodontitis is ≥ 2 sites with PD ≥ 4 mm, CAL ≥ 2 mm and BOP (+); for severe periodontitis is ≥ 1 sites with PD ≥ 4 mm, CAL ≥ 6 mm and BOP (+); for moderate periodontitis is ≥ 2 sites with PD ≥ 4 mm, CAL ≥ 3 mm and BOP (+), but not meet the criteria for severe periodontitis.

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Conflicts of interest

The authors reported no conflicts of interest related to this study.

Author contribution

Dr Xi Yan PEI designed the study, analysed the data and prepared the manuscript; Dr Lu HE designed the study and revised the manuscript; Prof Xiang Ying OUYANG designed and supervised the study and revised the manuscript.

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