ORIGINAL ARTICLE

Diagnostic performance of the AAP/EFP classification and the CDC/AAP case definition among pregnant women and a practical screening tool for maternal periodontal diseases

Hui-Jun Li[1] | Dan Zhao[2,3] | Xiaoyi Xu[1] | Rong Yu[1] | Feng Zhang[1] | Tianfan Cheng[3] | Zheng Zheng[4] | Hong Yang[4] | Chuanzhong Yang[5] | Jilong Yao[4] | Ping Wen[6] | Lijian Jin[3]

[1]Division of Stomatology, Shenzhen Maternity & Child Healthcare Hospital, Shenzhen, China

[2]Beijing Stomatological Hospital, Capital Medical University, Beijing, China

[3]Division of Periodontology & Implant Dentistry, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China

[4]Division of Obstetrics & Gynecology, Shenzhen Maternity & Child Healthcare Hospital, Shenzhen, China

[5]Division of Neonatology, Shenzhen Maternity & Child Healthcare Hospital, Shenzhen, China

[6]Division of Science & Education, Shenzhen Maternity & Child Healthcare Hospital, Shenzhen, China

Correspondence
Lijian Jin, Division of Periodontology & Implant Dentistry, Faculty of Dentistry, The University of Hong Kong, 34 Hospital Road, Hong Kong, China.
Email: ljjin@hku.hk

Ping Wen, Shenzhen Maternity & Child Healthcare Hospital, Shenzhen, China.
Email: kjkwenping@smu.edu.cn

Funding information
The Shenzhen/Hong Kong Innovation Circle Programme-Type D project from the Science, Technology & Innovation Commission of Shenzhen Municipal Government (PI: Prof. L.J. Jin), Grant/Award Number: SGDX2019081623060946; The Research and Transformation Platform for Maternal

Abstract

Background and Objective: There is a limited number of studies on the performance assessment of the 2017 AAP/EFP classification and the CDC/AAP case definition among pregnant females. This study evaluated the agreement between these two systems and explored a practical tool for screening maternal periodontal diseases by general dentists.

Materials and Methods: Totally, 204 systemically healthy females at different phases of pregnancy underwent a full-mouth periodontal examination. Demographic characteristics, lifestyles, and systemic conditions were recorded. Referring to the CDC/AAP definition, the diagnostic performance of the AAP/EFP classification was evaluated by the area under the ROC curve (AUC) and statistical tests (e.g., Youden's index and kappa coefficient). Additionally, a modified scoring system of the FDI Periodontal Diseases Chairside Guide (FDI-CG) was formulated with the addition of pregnancy for testing accordingly.

Results: Overall, there were 22.1% of the participants in early phase of pregnancy (7–13 weeks) and 77.9% in late phase (34–36 weeks). The majority of them were below 35 years and non-smokers without gestational diabetes. Notably, 30.9% of subjects presented with Moderate/Severe periodontitis (CDC/AAP), and 35.8% with Stages II-IV periodontitis (AAP/EFP). Referring to the CDC/AAP definition, the AUC, Youden's index, and κ of the AAP/EFP classification were 0.979, 0.890, and 92.9%, respectively. The modified FDI-CG system improved the AUC (0.815), Youden's index (63.0%), and κ (0.544) with reference to the original one.

Conclusions: This study shows that the AAP/EFP classification is in high agreement with the CDC/AAP definition among the pregnant women. The phases of pregnancy-integrated FDI scoring system may serve as a convenient screening tool for maternal periodontal diseases in general dental practice.

and Child Oral Health Promotion &
Disease Control in the Guangdong-Hong
Kong-Macao Greater Bay Area

1 | INTRODUCTION

Periodontal diseases are among the major public health burdens worldwide, with considerable effects on oral health and general health like diabetes mellitus (DM), cardiovascular disease (CVD), and adverse pregnancy outcomes (APOs) as well as high socioeconomic impacts.[1–5] Notably, oral cavity as an important ecological niche plays a critical role in the infection and spread of SARS-CoV-2, the major causative virus of COVID-19 pandemic.[6] Indeed, periodontitis could increase the risk of COVID-19 and its complications.[7–9] Therefore, increasing public awareness of periodontal health and enhancing prevention and professional care are of great importance for oral health and general well-being.

Pregnant women are prone to notable changes in oral and periodontal tissues, mainly due to increased levels of progesterone and estrogen as well as altered lifestyles. It has been well documented that pregnancy could significantly account for increased gingival inflammation and severity of periodontitis, concurrently with the high burden of dysbiotic bacteria and upregulated immuno-inflammatory responses as well as potential aggravation of periodontal diseases and related inflammatory comorbidities.[10–13] Conceivably, pregnancy increases to different extents the risk of gingivitis and periodontitis.[14]

Within the framework of periodontal medicine, periodontal diseases have been claimed for the potential link to 57 systemic diseases and disorders.[15] Of them, DM, CVD, and APOs have been highlighted in an updated comprehensive review.[4] APOs are important public health problems with significant socioeconomic implications.[16] In the last two decades, many researchers have explored the association of maternal periodontal diseases with preterm birth (PTB), low birth weight (LBW), and preeclampsia.[17–23] Overall, periodontal diseases may increase the risk of APOs.[4,24] While, the strength of such association could be modest and heterogeneous, according to the subject profiles, assessment approaches, and case definitions.[25] Further investigations are needed to clarify whether periodontal intervention may directly contribute to reducing the risk of APOs.[16,26,27]

Oral/periodontal healthcare is an important element of comprehensive maternity care. It is noteworthy that the American Academy of Periodontology (AAP) has well established a guideline on the periodontal treatment of pregnant women since 2004, for their well-being and healthy newborn babies,[27] whereas there is a relatively high prevalence of periodontal diseases among pregnant females in both developed and developing countries.[28,29] However, oral/periodontal health is often neglected, and the pregnant mothers are often unable to receive oral healthcare via regular dental visits.[29] In line with the comprehensive maternity care and support, strengthening periodontal health literacy, screening, and appropriate assessment with a proper case definition is, therefore, essential to early identify gingivitis and periodontitis patients and to deliver individualized healthcare in daily dental practice.

The criterion of the Centers for Disease Control and Prevention and American Academy of Periodontology (CDC/AAP) has been widely used.[30] While the current classification scheme of periodontal and peri-implant diseases and conditions, jointly presented by the AAP and the European Federation of Periodontology (AAP/EFP), has been launched since 2018.[31–33] Recently, several population-based studies have reported the diagnostic performance and agreement between the CDC/AAP system and AAP/EFP classification.[34–36] Currently, there is a lack of such comparative studies on these diagnostic systems in pregnant females. It has been shown that different diagnostic approaches considerably account for the variation in the prevalence of periodontitis among pregnant women.[37] Additionally, appropriate screening tools for maternal periodontal diseases are needed in general dental practice. Thus, the present study was to compare the profile of periodontal diseases among pregnant women using the CDC/AAP and AAP/EFP systems and attempted to develop a clinically applicable and easy-to-use tool for screening maternal periodontal diseases by general dentists.

2 | MATERIALS AND METHODS

2.1 | Subjects

This cross-sectional study was conducted in a sample of Chinese pregnant women recruited from the clinic of the Department of Obstetrics & Gynecology at the Shenzhen Maternity and Child Healthcare Hospital (SZMCH) from August 2020 to July 2021. The exclusion criteria included (i) ≥36 years old; (ii) edentulism; (iii) use of antibiotics within 3 months; (iv) periodontal treatment received within 12 months; (v) self-reported systemically unhealthy prior to pregnancy; and (vi) history of pathological abortion confirmed by medical records. This study was approved by the Medical Ethics Committee of SZMCH (No. SFYLS [2020]013), and oral and written consents were obtained from all subjects prior to the study. This study was conducted in line with the Declaration of Helsinki 2013.

2.2 | Periodontal examination and data collection

All subjects underwent a full-mouth periodontal examination (6 sites/tooth) by a single calibrated examiner (HJL), using a periodontal probe (UNC-15; Hu Friedy). The intra-examiner reliability was assessed by repeated measurements at site level in four subjects. Intraclass correlation coefficient (ICC) was calculated, with

0.887 (95% CI: 0.860–0.909) for the absolute agreement on probing depth (PD) and 0.873 (95% CI: 0.829–0.905) on clinical attachment loss (CAL), respectively. The periodontal parameters were then recorded, including full-mouth plaque score (FMPS), bleeding on probing (BOP), PD, furcation involvement, tooth mobility, number of tooth loss due to periodontitis (excluding the third molar), and number of remaining teeth. CAL was calculated on the basis of PD and the gingival margin level relative to the cementoenamel junction.

2.3 | Case definitions

All subjects were classified following the CDC/AAP[30] and the AAP/EFP systems.[31,33,38,39] In the present study, according to the CDC/AAP definition, Severe periodontitis was defined as the presence of ≥2 interproximal sites on different teeth with CAL ≥6 mm and ≥one interproximal site with PD ≥5 mm. Moderate periodontitis was defined as having ≥2 interproximal sites on different teeth with CAL ≥4 mm or ≥2 interproximal sites with PD ≥5 mm. All subjects without Severe or Moderate periodontitis were defined as Mild periodontitis or No periodontitis, respectively. With reference to the AAP/EFP classification,[31,33] periodontitis was defined as exhibiting interdental CAL at ≥2 non-adjacent teeth, or buccal/oral CAL ≥3 mm with PD >3 mm at ≥2 teeth. Gingivitis was defined as the presence of gingival inflammation (BOP ≥10% of sites) and the absence of detectable CAL due to periodontitis.[38] Periodontal health was defined as the absence of gingival inflammation (BOP <10% of sites) and the absence of CAL resulting from periodontitis.[38,39] As the radiographic examination was not performed in this study, grading was not given in the final classification of periodontitis. For staging, Mild periodontitis (Stage I), Moderate periodontitis (Stage II), and Severe periodontitis (Stages III and IV) were defined, respectively, on the basis of interdental CAL at the most affected sites (1–2, 3–4 and ≥5 mm).[31]

The FDI Periodontal Diseases Chairside Guide (FDI-CG) was developed in 2018 as an easy-to-use screening tool for general dentists in clinical practice, and it has recently been validated in three selected samples from Europe and Asia.[40,41] The 7-item scoring system of FDI-CG for periodontal disease profiling consists of age, tobacco smoking, diabetes mellitus, tooth loss due to periodontitis, plaque deposits, BOP, and PD.[40] Each item is ranged from 0 to 2 or 3, and the total score is then calculated accordingly. Individual profile of periodontal diseases is then categorized into three levels accordingly, namely Mild (0–5), Moderate (6–10), and Severe (≥ 11).[40]

2.4 | Sample size estimation and statistical analysis

Estimation of sample size was performed using a software (Power Analysis & Sample Size Software: PASS 2021, NCSS). According to our recent data from 141 adult subjects in Hong Kong, the sensitivity and specificity of identifying Moderate periodontitis with the AAP/EFP classification and CDC/AAP definition as the reference modality were 100.0% and 47.4%, respectively. For these childbearing-age women,

the present study set the expected sensitivity of 100.0% and specificity of 60%. Therefore, at least 42 Moderate periodontitis patients and 127 No or Mild periodontitis subjects were needed by a 5% significance level tested with 80% power. The total sample size was then set as minimally 200, considering the possible no-show participants and potentially higher prevalence of periodontitis in China.[28]
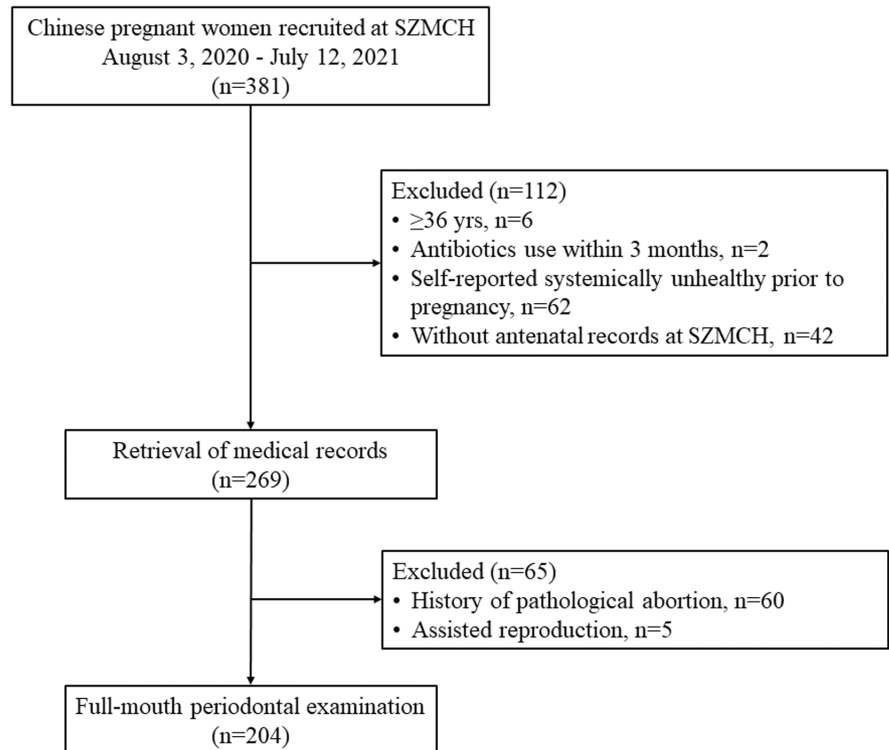
The data analysis was conducted with a software (Version 9.4 SAS Institute Inc.). All results were presented as mean±standard deviations (SD), median (interquartile range) or number/percentage (%) as appropriate. With the CDC/AAP definition as the reference modality, the area under the ROC (receiver operating characteristic) curve (AUC) for AAP/EFP classification and FDI-CG scoring system were calculated, respectively. For the AUC analysis, the subjects with Moderate or Severe periodontitis and the others were categorized, respectively, into Moderate/Severe group (moderate to severe periodontitis) and No/Mild group (periodontal health, gingivitis and mild periodontitis). To correlate with CDC/AAP definition, the cut-off level should be Stage II periodontitis for the AAP/EFP classification and a score of 6 for the FDI-CG system. Regarding the original version of FDI-CG scoring system, a new item was added for pregnant women, and two versions of the system were established for testing. One version was that pregnancy would be scored with 2 additional points (FDI-CG all +2). Another one was that early phase of pregnancy was scored with 1 additional point, and late phase of pregnancy was given 2 additional points (FDI-CG early phase +1 and late phase +2). Diagnostic tests were undertaken to measure the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Youden's index. Furthermore, the agreement of the three approaches was analyzed by the kappa coefficient (κ), and α was adjusted to 0.0167 (two-sided) by Bonferroni test for multiple tests. The statistical significance level was set at 0.05 (two-sided).

3 | RESULTS

3.1 | Demographic characteristics of the subjects

A total of 381 Chinese women in the early and late phases of pregnancy were recruited. Of them, two subjects taking antibiotics in the preceding 3 months and six subjects with age ≥36 years were excluded. Moreover, 62 participants self-reported systemically unhealthy prior to pregnancy and 42 not having medical records in the database of SZMCH were not recruited. Of the remaining 269 subjects, 60 with a history of pathological abortion and 5 with a record of assisted reproduction were further excluded. Finally, 204 pregnant females (29.8±2.5 years, ranged 24–35 years) were included in the study for subsequent assessments (Figure 1). There were 45 (22.1%) subjects in the early phase of pregnancy (7–13 weeks) and 159 (77.9%) in the late phase of pregnancy (34–36 weeks) (Table 1). Most of them (70.1%) had 28 teeth excluding the third molars, and the main cause of tooth loss for the rest was caries and tooth extraction for orthodontic treatment. There were five subjects aged 35 yrs and two former smokers. The item of diabetes in the FDI-CG was

```
Chinese pregnant women recruited at SZMCH
August 3, 2020 - July 12, 2021
(n=381)

Excluded (n=112)
• ≥36 yrs, n=6
• Antibiotics use within 3 months, n=2
• Self-reported systemically unhealthy prior to
  pregnancy, n=62
• Without antenatal records at SZMCH, n=42

Retrieval of medical records
(n=269)

Excluded (n=65)
• History of pathological abortion, n=60
• Assisted reproduction, n=5

Full-mouth periodontal examination
(n=204)
```

modified with gestational diabetes, and there was only one subject with controlled gestational diabetes (HbA1c < 7.0%).

3.2 | Periodontal status

91.7% of the subjects presented with over 50% of sites with plaque, and 70.6% showed 10%–50% of sites with BOP. The majority of them (84.8%) exhibited PD <4 mm or 4–5 mm. None had tooth loss due to periodontitis. As the total score of disease profile based on the FDI-CG was not normally distributed, the median (interquadrant range) of the score was presented (4, 3–4).

The overall periodontal condition varied with the three case definitions used (Table 2). According to the CDC/AAP definition, 69.1% of subjects presented with Mild or No periodontitis and 30.4% with Moderate periodontitis. Based on the AAP/EFP classification, 22.5% exhibited periodontally healthy status, 19.6% with gingivitis, and various stages of periodontitis (I: 22.1%, II: 23.5%, and III: 25, 12.3%). None of the subjects had Stage IV periodontitis. While scoring by FDI-CG, the majority (93.1%) got scores 0–5 (Mild) and 6.9% had scores 6–10 (Moderate), and no one had total score over 10 (Severe).

3.3 | Performance assessment of the AAP/EFP classification and FDI-CG scoring system with reference to the CDC/AAP definition

AUC was calculated for the assessment results of AAP/EFP classification and FDI-CG scoring system, respectively, with reference to the CDC/AAP definition (Figure 2). To distinguish subjects from

No/Mild periodontitis group or Moderate/Severe periodontitis group, the AUC based on AAP/EFP classification (Model 1) was 0.979 (95% CI: 0.963–0.995) with the optimal cut-off for Stage II. For the FDI-CG scoring system, three testing models were built to find out the most appropriate one among these pregnant women. According to the original version with a cut-off score of 6 (FDI-CG original model, Model 2), the AUC was 0.600 (95% CI: 0.510, 0.689). Notably, the AUC for those two adjusted versions improved markedly from 0.600 (Model 2) to 0.809 (FDI-CG all +2, Model 3) and 0.815 (FDI-CG early phase +1 and late phase +2, Model 4), respectively ($p < .001$). Accordingly, the proportion of subjects scoring 6–10 (Moderate) increased to 57.3% (FDI-CG all +2) and 48.5% (FDI-CG early phase +1 and late phase +2), respectively (Table 2). None of them got scores over 10 in these two additional models.

The sensitivity, specificity, PPV, NPV, and Youden's index were further calculated to clarify the diagnostic performance of both AAP/EFP and FDI-CG systems with the CDC/AAP as the reference (Table 3). In general, the AAP/EFP system exhibited excellent dichotomous diagnostic performance (Youden's index: 92.9%) with a high sensitivity (100.0%), specificity (92.9%), PPV (86.3%), and NPV (100%), while the original FDI-CG system exhibited the highest specificity and PPV, and the two modified FDI-CG scoring systems demonstrated similar sensitivity and NPV which were higher than those of the original one. Moreover, the adjusted FDI-CG models showed greater performance as indicated by the Youden's index (>60.0%) with reference to the original one (19.9%). Herein, the modified FDI-CG (early phase +1 and late phase +2) model performed slightly better than another modified one (all +2) model.

TABLE 1 Demographic characteristics and periodontal status following the FDI-CG scoring system

Characteristics	Mean ± SD / Median (IQR) / N (%)
Gestational age	
7–13 weeks	45 (22.1)
34–36 weeks	159 (77.9)
Number of remaining teeth	
≤24	6 (2.9)
25–27	55 (27.0)
≥28	143 (70.1)
FDI-CG scoring system	
Age	29.8 ± 2.5
<35	199 (97.5)
35–44	5 (2.5)
Smoking status	
Non-smoker	202 (99.0)
Former smoker	2 (1.0)
Current smoker	0 (0.0)
Diabetes	
No	203 (99.5)
Well-controlled (HbA1C < 7%)	1 (0.5)
Poor-controlled (HbA1C ≥ 7%)	0 (0.0)
FMPS	
<10% of tooth sites	0 (0.0)
10%–50% of tooth sites	17 (8.3)
>50% of tooth sites	187 (91.7)
BOP	
<10% of tooth sites	46 (22.5)
10%–50% of tooth sites	144 (70.6)
>50% of tooth sites	14 (6.9)
PD	
<4 mm	86 (42.2)
4–5 mm	87 (42.6)
Localized tooth sites >5 mm	25 (12.3)
Generalized tooth sites >5 mm	6 (2.9)
Tooth loss due to periodontitis	
No	204 (100.0)
Yes	0 (0.0)
FDI-CG	4 (3,4)

Abbreviations: BOP, bleeding on probing; FDI-CG, FDI periodontal diseases chairside guide; FMPS, full-mouth plaque score; IQR, interquartile range; PD, probing depth; SD, standard difference.

3.4 | Overall assessment agreements of the three case definitions

The diagnoses of Moderate and Severe periodontitis with different case definitions showed varying agreements (Table 4). There was almost a perfect agreement between the AAP/EFP and CDC/

TABLE 2 Periodontal status assessed with the three different case definitions

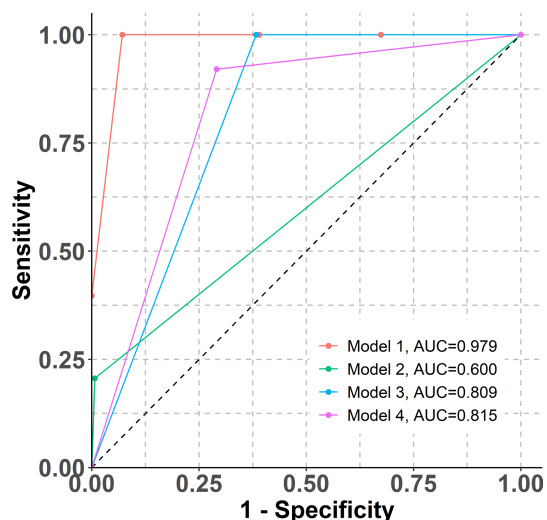| Case definitions	N (%)
CDC/AAP	
No & mild	141 (69.1)
Moderate	62 (30.4)
Severe	1 (0.5)
AAP/EFP	
Healthy	46 (22.5)
Gingivitis	40 (19.6)
Stage I	45 (22.1)
Stage II	48 (23.5)
Stage III	25 (12.3)
Stage IV	0 (0.0)
FDI-CG	
Mild (0–5)	190 (93.1)
Moderate (6–10)	14 (6.9)
Severe (>10)	0 (0.0)
FDI-CG (all + 2)	
Mild (0–5)	87 (42.6)
Moderate (6–10)	117 (57.3)
Severe (>10)	0 (0.0)
FDI-CG (early + 1 and late + 2)	
Mild (0–5)	105 (51.4)
Moderate (6–10)	99 (48.5)
Severe (>10)	0 (0.0)

Abbreviation: FDI-CG, FDI periodontal diseases chairside guide.

AAP ($\kappa = 0.890$, $p < .001$), while the consistencies of the FDI-CG original model with CDC/AAP and AAP/EFP were fair ($\kappa = 0.254$ and 0.234, respectively, $p < .001$). Notably, the FDI-CG (all +2) model revealed moderate agreement with both CDC/AAP and AAP/EFP classifications having a kappa value of 0.499 and 0.586, respectively ($p < .001$). Moreover, the modified FDI-CG (early phase +1 and late phase +2) model further improved the agreement with CDC/AAP case definition from 0.499 to 0.544, while both adjusted FDI-CG models exhibited similar agreements with the AAP/EFP classification (0.585 vs. 0.586).

4 | DISCUSSION

The present study firstly shows that the overall profile of periodontal conditions in the pregnant women investigated was consistent, using the CDC/AAP and AAP/EFP systems. Then, a practical screening tool was explored for maternal periodontal diseases by general dentists. According to the CDC/AAP system, the AUC for AAP/EFP classification to distinguish Moderate/Severe periodontitis (Stages II-IV) from No/Mild periodontitis (periodontal health, gingivitis, and Stage I periodontitis) was 0.979. As anticipated, the

diagnostic performance of AAP/EFP (92.9%) was excellent.[35] The agreement of CDC/AAP with AAP/EFP was high (89.0%) as well. Moreover, the modified FDI-CG scoring systems with the addition of maternal phases as a new item markedly improved the AUC up to 0.815 and thereby enhanced the diagnostic performance to 63.0%. The agreement of the modified FDI-CG (early +1 and late +2) model with CDC/AAP definition was the highest among the three FDI-CG models, while the two modified FDI-CG models had similar agreements with AAP/EFP classification. It should be noted that the pregnant women with generally young age and

low prevalence of severe periodontitis to some extent may have affected the results and the external validity.

Periodontal diagnosis is traditionally made on the basis of assessing the presence and extent of PD, CAL, and the profile of alveolar bone loss on radiographs, and subsequently the patients are generally categorized as mild, moderate, or severe cases,[30] whereas these periodontal parameters reflect different aspects of periodontitis. High PD values denote currently existing lesions, while CAL and bone loss are the measurements of accumulated periodontal destruction.[42] Indeed, the lack of generally accepted case definitions of periodontitis is a long-standing challenge for effective surveillance of periodontitis, and it has therefore been considered as a major issue in determining and comparing the prevalence of a disease across various surveys worldwide.[43] The current AAP/EFP classification consists of the newly added periodontal/gingival health, classical form of plaque biofilm-induced gingivitis and periodontitis that is multidimensionally subcategorized by Stages I-IV/Grades A-C with the extent of disease and potential complexity of treatments.[31,32] Certainly, it is the great breakthrough for appropriate assessment and diagnosis of periodontal patients. The accuracy and comprehensiveness of the AAP/EFP classification are the great advantages for patient assessment, diagnosis, formulation of treatment plan, and subsequent therapies in clinical practice, whereas for the purposes of clinical screening, estimation of treatment needs and population-based epidemiological studies, the critical elements such as easiness, convenience, operation time, and participants' acceptance need to be considered in developing the relevant systems.

The FDI-CG scoring system as an easy-to-use screening tool has recently been validated in a multicenter study with reference to the CDC/AAP system.[41] This 7-item scoring tool primarily includes age, measurement of disease experience (tooth loss due to periodontitis), existing plaque control and periodontal condition (plaque score, BoP, and PD) and the important risk factors (tobacco use and diabetes) that are integrated in the current AAP/EFP classification.[40] This tool allows general dental practitioners to quickly and conveniently perform periodontal screening in daily practice and give relevant professional advice to their patients. Here, some items like age and tobacco smoking may be not highly applicable to many pregnant women. Meanwhile,

FIGURE 2 ROC curves for discriminating subjects with or without Moderate/Severe periodontitis with reference to CDC/AAP case definition. Model 1 (red line): AAP/EFP classification; Model 2 (green line): FDI-CG scoring system (FDI-CG original model); Model 3 (blue line): FDI-CG scoring system with two scores added for pregnancy (FDI-CG all +2); and Model 4 (pink line): FDI-CG scoring system with one score added for early phase of pregnancy and two scores added for late phase of pregnancy (FDI-CG early +1 and late phase +2). Significant difference was detected by pairwise comparison except for Model 3 versus Model 4 (*p* < .001). ROC, receiver operating characteristic; FDI-CG, FDI periodontal diseases chairside guide

TABLE 3 Comparison of diagnostic performance of AAP/EFP classification and FDI-CG scoring system on identifying subjects with moderate/severe periodontitis diagnosed with the CDC/AAP case definition

Periodontitis case definitions	CDC/AAP case definition								
	Sensitivity		Specificity		PPV		NPV		Youden's index
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%
AAP/EFP	100.0	94.3–100.0	92.9	87.4–96.1	86.3	76.6–92.4	100.0	97.2–100.0	92.9
FDI-CG	20.6	12.5–32.2	99.3	96.1–100.0	92.3	68.5–99.6	73.7	67.0–79.4	19.9
FDI-CG (all +2)	100.0	94.3–100.0	61.7	53.5–69.3	53.9	44.8–62.6	100.0	95.7–100.0	61.7
FDI-CG (early +1 and late +2)	92.1	82.7–96.6	70.9	63.0–77.8	58.6	48.7–67.8	95.2	89.3–98.0	63.0

Abbreviations: CI, confidence interval; FDI-CG, FDI periodontal diseases chairside guide; NPV, negative predictive value; PPV, positive predictive value.

TABLE 4 Comparison of periodontal conditions assessed with the three different case definitions

Periodontitis case definitions	CDC/AAP case definition			AAP/EFP case definition		
	No & mild (N = 141)	Moderate & Severe (N = 63)	Kappa (κ)	Healthy or gingivitis or Stage I (N = 131)	Stage II & III (N = 73)	Kappa (κ)
AAP/EFP						
Healthy or gingivitis or Stage I	131 (92.9)	0 (0.0)	0.890[a]			
Stage II & III	10 (7.1)	63 (100.0)				
FDI-CG						
Mild (0–5)	140 (99.3)	50 (79.4)	0.254[a]	131 (100.0)	59 (80.8)	0.234[a]
Moderate & Severe (6–10)	1 (0.7)	13 (20.6)		0 (0.0)	14 (19.2)	
FDI-CG (all + 2)						
Mild (0–5)	87 (61.7)	0 (0.0)	0.499[a]	87 (66.4)	0 (0.0)	0.586[a]
Moderate & Severe (6–10)	54 (38.3)	63 (100.0)		44 (33.6)	73 (100.0)	
FDI-CG (early + 1 and late + 2)						
Mild (0–5)	100 (70.9)	5 (7.9)	0.544[a]	97 (74.0)	8 (11.0)	0.585[a]
Moderate & Severe (6–10)	41 (29.1)	58 (92.1)		34 (26.0)	65 (89.0)	

Abbreviation: FDI-CG, FDI periodontal diseases chairside guide.
[a]$p < .001$.

considering the anticipated risk of periodontal diseases, it is proposed to add pregnancy as an essential item in the FDI-CG scoring system for appropriately screening periodontal conditions among the mothers-to-be. Furthermore, it remains to be a debatable clinical issue whether radiographic examination should be included in a routine periodontal examination during the period of pregnancy,[44,45] although it is needed for determining the grade of periodontitis with the AAP/EFP classification. It is worth noting that radiographic examination is purposely not included in the FDI-CG scoring system as a practical and convenient screening tool.[40] Taken together, the proposed phases of pregnancy-integrated FDI scoring system could be used for periodontal screening, disease prevention, and periodontal healthcare in line with the clinical guideline among the mothers-to-be.

AUC was used to demonstrate the ability of disease prediction and the appropriate cut-off value for an ordinary or continuous variable accordingly. Diagnostic performance presents how accurate the subjects are distinguished by a new definition as compared to the previous one. However, only when every single subject has same diagnosis by two different case definitions, a high agreement could be achieved. Recently, several studies have focused on the comparison of CDC/AAP and AAP/EFP case definitions; and AUC, diagnostic performance, and agreement have been used appropriately.[34–36,46] Overall, these studies show the high agreement of AAP/EFP classification with CDC/AAP system.

It is apparent that maternal oral/periodontal healthcare is crucial for the general health and well-being of the mothers and their babies.[4,23] There are anticipated dynamic changes in oral cavity during the period of pregnancy and postpartum, due to various alterations in lifestyle factors, personal behaviors, stress, and the well-noted

fluctuations of sex hormones (estrogen and progesterone). These factors and conditions to varying extents may collectively account for dysregulated inflammatory responses and decreased immunocompetence, thereby increasing the host susceptibility to the onset and progression of oral diseases.[47,48] Meanwhile, these changes in periodontium could complicate periodontal assessment and diagnosis to be appropriately performed by general dentists. It is, therefore, desirable to set up an easy and convenient tool for screening periodontal conditions of pregnant women, in order to enhance maternal oral healthcare in general dental practice.

Currently, early diagnosis of periodontal diseases remains a considerable challenge, partly due to relatively low awareness of oral/periodontal health in the public community.[49–51] Indeed, the quality of life in periodontal patients can be significantly affected when advanced stages of periodontitis occur.[52] Obviously, awareness of periodontal healthcare and health literacy should be re-enforced for improving early diagnosis, disease prevention, and timely intervention.[53] General dentists need to promote effective oral hygiene practice and routinely deliver preventive care. As such, effective screening and assessment tools are critical to identify susceptible individuals and thereby undertake proactive professional healthcare as early as possible.[54] For the childbearing women with potentially increased risk of gingivitis and progression of periodontitis, it is imperative to enhance periodontal health literacy and help them adopt good oral hygiene regimen through regular dental visits prior to getting pregnant.[55] In addition, essential oral/periodontal care could be delivered appropriately through a mid-pregnancy dental appointment, and yet preventive healthcare and necessary treatments need to be undertaken for mothers during the postpartum dental visits.[56]

Therefore, an easy and effective screening tool like the modified FDI-CG scoring system with a reasonable diagnostic performance could facilitate oral/periodontal health promotion, early identification of diseases, and effective healthcare during the periods of pre-pregnancy, pregnancy, postpartum, and lactating. Further studies on different ethnic groups are needed to refine the modified FDI-CG screening system, through appropriate integration with the current AAP/EFP classification and potential diagnostic biomarkers.

5 | CONCLUSIONS

Within the limitations of the study, the present work demonstrates that the AAP/EFP classification has a high agreement with the CDC/AAP definition among pregnant females. The modified FDI-CG scoring system with the addition of pregnant phases may serve as a relatively easy-to-use and convenient tool for screening maternal periodontal diseases in general dental practice.

AUTHOR CONTRIBUTIONS

L.J.J. contributed to conceptualization and critical revision of the manuscript; D.Z., T.C., P.W., and L.J.J. contributed to study design; H.L., P.W., X.X., R.Y., and F.Z. involved in data acquisition; D.Z. and X.X. involved in data analysis; H.L., D.Z., Z.Z., H.Y., C.Y., J.Y., P.W., and L.J.J. contributed to data interpretation; H.L., D.Z., X.X., F.Z., T.C., and P.W. involved in writing draft; All authors reviewed and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

CONFLICT OF INTEREST

All authors declare they have no conflicts of interest related to this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Dan Zhao https://orcid.org/0000-0002-0037-1464
Lijian Jin https://orcid.org/0000-0002-5340-9710

REFERENCES

1. Jin LJ, Lamster IB, Greenspan JS, Pitts NB, Scully C, Warnakulasuriya S. Global burden of oral diseases: emerging concepts, management and interplay with systemic health. *Oral Dis.* 2016;22:609-619.

2. Tonetti MS, D'Aiuto F, Nibali L, et al. Treatment of periodontitis and endothelial function. *N Engl J Med.* 2007;356:911-920.

3. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: a call for global action. *J Clin Periodontol.* 2017;44:456-462.

4. Beck JD, Papapanou PN, Philips KH, Offenbacher S. Periodontal medicine: 100 years of progress. *J Dent Res.* 2019;98:1053-1062.

5. Listl S, Galloway J, Mossey PA, Marcenes W. Global economic impact of dental diseases. *J Dent Res.* 2015;94:1355-1361.

6. Marchesan JT, Warner BM, Byrd KM. The "oral" history of COVID-19: primary infection, salivary transmission, and post-acute implications. *J Periodontol.* 2021;92:1357-1367.

7. Marouf N, Cai W, Said KN, et al. Association between periodontitis and severity of COVID-19 infection: a case-control study. *J Clin Periodontol.* 2021;48:483-491.

8. Wang Y, Deng H, Pan Y, et al. Periodontal disease increases the host susceptibility to COVID-19 and its severity: a mendelian randomization study. *J Transl Med.* 2021;19:528.

9. Anand PS, Jadhav P, Kamath KP, Kumar SR, Vijayalaxmi S, Anil S. A case-control study on the association between periodontitis and coronavirus disease (COVID-19). *J Periodontol.* 2022;93:584-590.

10. Kumar PS. Sex and the subgingival microbiome: do female sex steroids affect periodontal bacteria? *Periodontol 2000.* 2000;2013(61):103-124.

11. Nuriel-Ohayon M, Neuman H, Koren O. Microbial changes during pregnancy, birth, and infancy. *Front Microbiol.* 2016;7:1031.

12. Fujiwara N, Tsuruda K, Iwamoto Y, et al. Significant increase of oral bacteria in the early pregnancy period in Japanese women. *J Investig Clin Dent.* 2017;8:e12189.

13. Balan P, Chong YS, Umashankar S, et al. Keystone species in pregnancy gingivitis: a snapshot of oral microbiome during pregnancy and postpartum period. *Front Microbiol.* 2018;9:2360.

14. Mascarenhas P, Gapski R, Al-Shammari K, Wang HL. Influence of sex hormones on the periodontium. *J Clin Periodontol.* 2003;30:671-681.

15. Monsarrat P, Blaizot A, Kemoun P, et al. Clinical research activity in periodontal medicine: a systematic mapping of trial registers. *J Clin Periodontol.* 2016;43:390-400.

16. Bobetsis YA, Graziani F, Gursoy M, Madianos PN. Periodontal disease and adverse pregnancy outcomes. *Periodontol 2000.* 2000;2020(83):154-174.

17. Offenbacher S, Katz V, Fertik G, et al. Periodontal infection as a possible risk factor for preterm low birth weight. *J Periodontol.* 1996;67(Suppl 10S):1103-1113.

18. Boggess KA, Lieff S, Murtha AP, Moss K, Beck J, Offenbacher S. Maternal periodontal disease is associated with an increased risk for preeclampsia. *Obstet Gynecol.* 2003;101:227-231.

19. Michalowicz BS, Hodges JS, DiAngelis AJ, et al. Treatment of periodontal disease and the risk of preterm birth. *N Engl J Med.* 2006;355:1885-1894.

20. Heimonen A, Janket SJ, Kaaja R, Ackerson LK, Muthukrishnan P, Meurman JH. Oral inflammatory burden and preterm birth. *J Periodontol.* 2009;80:884-891.

21. Puertas A, Magan-Fernandez A, Blanc V, et al. Association of periodontitis with preterm birth and low birth weight: a comprehensive review. *J Matern Fetal Neonatal Med.* 2018;31:597-602.

22. Contreras A, Herrera JA, Soto JE, Arce RM, Jaramillo A, Botero JE. Periodontitis is associated with preeclampsia in pregnant women. *J Periodontol.* 2006;77:182-188.

23. Figuero E, Han YW, Furuichi Y. Periodontal diseases and adverse pregnancy outcomes: mechanisms. *Periodontol 2000.* 2000;2020(83):175-188.

24. Sanz M, Kornman K. Working group 3 of the joint EFP/AAP workshop. Periodontitis and adverse pregnancy outcomes: consensus

report of the joint EFP/AAP workshop on periodontitis and systemic diseases. *J Periodontol.* 2013;84:S164-S169.

25. Ide M, Papapanou PN. Epidemiology of association between maternal periodontal disease and adverse pregnancy outcomes - Systematic review. *J Periodontol.* 2013;84:S181-S194.

26. Ren H, Du M. Role of maternal periodontitis in preterm birth. *Front Immunol.* 2017;8:139.

27. Task force on periodontal treatment of pregnant women, American Academy of periodontology. American Academy of periodontology statement regarding periodontal Management of the Pregnant Patient. *J Periodontol.* 2004;75:495.

28. Jiao J, Jing WD, Si Y, et al. The prevalence and severity of periodontal disease in mainland China: data from the fourth National Oral Health Survey (2015-2016). *J Clin Periodontol.* 2021;48:168-179.

29. Erchick DJ, Rai B, Agrawal NK, et al. Oral hygiene, prevalence of gingivitis, and associated risk factors among pregnant women in Sarlahi District, Nepal. *BMC Oral Health.* 2019;19:2.

30. Page RC, Eke PI. Case definitions for use in population-based surveillance of periodontitis. *J Periodontol.* 2007;78:1387-1399.

31. Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: framework and proposal of a new classification and case definition. *J Periodontol.* 2018;89(Suppl 1):S159-S172.

32. Caton JG, Armitage G, Berglundh T, et al. A new classification scheme for periodontal and peri-implant diseases and conditions - introduction and key changes from the 1999 classification. *J Clin Periodontol.* 2018;45(Suppl 20):S1-S8.

33. Papapanou PN, Sanz M, Buduneli N, et al. Periodontitis: consensus report of workgroup 2 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *J Periodontol.* 2018;89(Suppl 1):S173-S182.

34. Brito LF, Taboza ZA, Silveira VR, Teixeira AK, Rego RO. Diagnostic accuracy of severe periodontitis case definitions: comparison of the CDC/AAP, EFP/AAP, and CPI criteria. *J Periodontol.* 2022;93(6):867-876. doi:10.1002/JPER.21-0365

35. Ortigara GB, Mario Ferreira TG, Tatsch KF, et al. The 2018 EFP/AAP periodontitis case classification demonstrates high agreement with the 2012 CDC/AAP criteria. *J Clin Periodontol.* 2021;48:886-895.

36. Morales A, Strauss FJ, Hammerle CHF, et al. Performance of the 2017 AAP/EFP case definition compared with the CDC/AAP definition in population-based studies. *J Periodontol.* 2021. doi:10.1002/JPER.21-0276. Online ahead of print.

37. Conceicao SDS, Gomes-Filho IS, Coelho JMF, et al. An accuracy study of the clinical diagnosis of periodontitis in pregnant women. *J Periodontol.* 2021;92:1243-1251.

38. Trombelli L, Farina R, Silva CO, Tatakis DN. Plaque-induced gingivitis: case definition and diagnostic considerations. *J Periodontol.* 2018;89(Suppl 1):S46-S73.

39. Chapple ILC, Mealey BL, Van Dyke TE, et al. Periodontal health and gingival diseases and conditions on an intact and a reduced periodontium: consensus report of workgroup 1 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *J Periodontol.* 2018;89(Suppl 1):S74-S84.

40. FDI World Dental Federation. Periodontal diseases chairside guide: prevention and patient management. https://www.fdiworlddental.org/periodontal-diseases-chairside-guide-prevention-and-patient-management. Accessed: May 20, 2022.

41. Adel-Khattab D, Montero E, Herrera D, et al. Evaluation of the FDI chairside guide for assessment of periodontal conditions: a multicentre observational study. *Int Dent J.* 2021;71:390-398.

42. Tonetti MS, Claffey N. European workshop in periodontology group C. advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research. Group C consensus report of the 5th European workshop in periodontology. *J Clin Periodontol.* 2005;32(Suppl 6):210-213.

43. Eke PI, Thornton-Evans GO, Wei L, Borgnakke WS, Dye BA. Accuracy of NHANES periodontal examination protocols. *J Dent Res.* 2010;89:1208-1213.

44. Kelaranta A, Ekholm M, Toroi P, Kortesniemi M. Radiation exposure to foetus and breasts from dental x-ray examinations: effect of lead shields. *Dentomaxillofac Radiol.* 2016;45:20150095.

45. American dental association council on scientific a. the use of dental radiographs: update and recommendations. *J Am Dent Assoc.* 2006;137:1304-1312.

46. Germen M, Baser U, Lacin CC, Firatli E, Issever H, Yalcin F. Periodontitis prevalence, severity, and risk factors: a comparison of the AAP/CDC case definition and the EFP/AAP classification. *Int J Environ Res Public Health.* 2021;18:3459.

47. Barak S, Oettinger-Barak O, Oettinger M, Machtei EE, Peled M, Ohel G. Common oral manifestations during pregnancy: a review. *Obstet Gynecol Surv.* 2003;58:624-628.

48. de Araujo S, Figueiredo C, Gonçalves Carvalho Rosalem C, Costa Cantanhede AL, Abreu Fonseca Thomaz ÉB. Fontoura Nogueira da Cruz MC. Systemic alterations and their oral manifestations in pregnant women. *J Obstet Gynaecol Res.* 2017;43:16-22.

49. Luo H, Wu B. Self-awareness of "gum disease" among US adults. *J Public Health Manag Pract.* 2017;23:e1-e7.

50. Watt RG, Petersen PE. Periodontal health through public health–The case for oral health promotion. *Periodontol 2000.* 2012;60(1):147-155.

51. Genco RJ, Genco FD. Common risk factors in the management of periodontal and associated systemic diseases: the dental setting and interprofessional collaboration. *J Evid Based Dent Pract.* 2014;14(Suppl):4-16.

52. Buset SL, Walter C, Friedmann A, Weiger R, Borgnakke WS, Zitzmann NU. Are periodontal diseases really silent? A systematic review of their effect on quality of life. *J Clin Periodontol.* 2016;43:333-344.

53. Deng K, Pelekos G, Jin L, Tonetti MS. Diagnostic accuracy of self-reported measures of periodontal disease: a clinical validation study using the 2017 case definitions. *J Clin Periodontol.* 2021;48:1037-1050.

54. Eke PI, Page RC, Wei L, Thornton-Evans G, Genco RJ. Update of the case definitions for population-based surveillance of periodontitis. *J Periodontol.* 2012;83:1449-1454.

55. California Dental Association Foundation, American College of Obstetricians and Gynecologists district IX. Oral health during pregnancy and early childhood: evidence-based guidelines for health professionals. *J Calif Dent Assoc.* 2010;38(6):391-403. 405–440.

56. Russell SL, Mayberry LJ. Pregnancy and oral health: a review and recommendations to reduce gaps in practice and research. *MCN Am J Matern Child Nurs.* 2008;33:32-37.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.