Original Article

Assessing the Significance of Periodontal Inflamed Surface Area (PISA) in Determining Periodontitis Severity

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Abstract

The Periodontal Inflamed Surface Area (PISA) is a novel parameter which quantifies the extent of periodontal inflammation. This cross-sectional study aimed to explore the association between the PISA value and conventional parameters, including mean probing pocket depth (PPD) and mean clinical attachment level (CAL). Additionally, the PISA value was compared across severity levels of periodontitis, as classified by the CPITN and CDC/AAP definitions in the Electricity Generating Authority of Thailand (EGAT) workers. PISA was calculated using full-mouth periodontal parameters including PPD, CAL, and bleeding on probing. Periodontitis, as defined by CPITN and CDC/AAP, was classified into no/mild, moderate, or severe periodontitis. The reliability of PISA compared with severity types of periodontitis defining by CPITN and CDC/AAP was explored by the Kruskal-Wallis test. Among a total of 2,643 participants aged 34-74 years, the median of PISA value was 319.4 mm^2 with a range of 2.2 to 3624.4 mm^2, and the mean of PISA value was 440.68±415.40 mm^2. When defining periodontitis according to CPITN and CDC/AAP, the prevalence of severe periodontitis were 28.7% and 26.3%, respectively. Pearson's correlation indicated that the correlation between PISA and mean PPD, as well as between PISA and mean CAL, was significant (p <0.001) with coefficients of 0.78 and 0.52, respectively. When comparing PISA values across severity levels, there were statistically significant (p <0.001) differences in PISA values among severity levels of periodontitis classified by CPITN and CDC/AAP. A dose-response relationship was also observed. Therefore, periodontal parameter represented by PISA had the significant association with conventional periodontal case definitions.

Keywords: Periodontal inflamed surface area (PISA), Periodontitis, Periodontal parameter

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Introduction

Various periodontal parameters and periodontitis case definitions have been employed in periodontal research without uniformity.[1-3] Comparisons throughout the literature have been limited by this disparity. In 1983, the World Health Organization (WHO) introduced the Community Periodontal Index of Treatment Needs (CPITN) as a primary screening criterion for disease severity and individual treatment recommendations.[4] Due to its simplicity, the CPITN index has been widely adopted in numerous epidemiological surveys and research studies.[5] However, some concerns have been raised regarding potential of under and over estimations as it considers calculus, gingival bleeding and probing pocket depths (PPD) measurements from only the index teeth.[6] Later, the Centers for Disease Control and Prevention (CDC), in collaboration with the American Academy of Periodontology (AAP), proposed periodontitis case definitions that were suggested for population-based surveillance. The CDC/AAP definitions classify periodontitis patients based on the full-mouth measurements of PPD and clinical attachment levels (CAL). With a complete examination and appropriate threshold values, these definitions properly indicate the disease severity by assessing cumulative periodontal destruction.[7] However, using them to discriminate the amount of periodontal inflammation and measure the actual disease activity may be not fully appropriate used.[8]

Recently, a novel periodontal parameter called the Periodontal Inflamed Surface Area (PISA) has been proposed to determine the level of periodontal inflammation. Advanced mathematical and geometric equations are utilized to estimate the root surface area of each specific tooth. Parameters such as PPD, gingival recession (RE), and CAL are taken into account to calculate the root area affected by periodontitis. Additionally, data is collected from all sites exhibiting bleeding on probing (BOP) to indicate inflamed periodontal tissue. The surface area of the inflamed pocket epithelium is then combined from all teeth to derive the PISA value. A high PISA value suggests a larger area of inflamed tissue, indicating a higher level of periodontal inflammation.[9]

Given these considerations, we hypothesize that PISA may offer a more precise representation of the current status of periodontal inflammation. However, scientific evidence confirming its reliability in discriminating periodontitis severity compared to conventional parameters has been limited. Therefore, this cross-sectional study aimed to explore the association between the PISA value and conventional parameters, including mean PPD and mean CAL. Additionally, the PISA value was compared across severity levels of periodontitis, as classified by the CPITN and CDC/AAP definitions.

Materials and methods

Study population

This cross-sectional study used the secondary data of the Electricity Generating Authority of Thailand (EGAT) project, which was the health survey among EGAT employees. Subjects who underwent medical and periodontal examination in 2018-2019 (EGAT 2/5 and 3/3) were included. They were excluded if they had less than 2 remaining teeth or had the health condition that were contraindications for periodontal examination. All subjects were formally informed on the study's objectives and protocol, and they provided written informed consent before participation. The study protocol received approval from the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022-040).

Periodontal examination and classification

The standard full-mouth periodontal examination was performed by a group of experienced and trained periodontists. PPD and RE of all fully erupted teeth were recorded, except third molars and retained roots. The BOP also marked from six sites of each tooth as present or absent. Calibration and standardization for periodontal measurements were carried out among examiners before the survey. Weighted kappa (±1 mm) was used to determine intra-examiner and inter-examiner agreements. The kappa coefficients for inter-examiner agreement on PPD and RE measurements were 0.74-1.00 and 0.72-1.00, respectively.

The intra-examiner kappa coefficients were 0.86-1.00 and 0.91-1.00, respectively.

PISA measurement

The PISA value was calculated based on the specific equations on available spreadsheet proposed by Nesse *et al.*[9] In brief, the periodontal epithelial surface area (PESA) was estimated by subtracting recession surface area (RSA) from attachment loss surface area (ALSA). Then, the PESA value for each tooth was multiplied by the proportion of sites which BOP was detected. The sum of PISA value from all individual teeth was summarized as the total PISA value for each participant.

CPITN and CDC/AAP case definitions

The presence of periodontal disease was defined according to the CPITN.[4] The modified CPI for clinical circumstance was applied. The highest PPD from the full-mouth examination was used for classification. CPI codes 0-2 were recognized as non-periodontitis. Subjects with CPI codes 3 and 4, or those with PPD of 4-5 mm and ≥6 mm, were classified as moderate and severe periodontitis, respectively. Additionally, the presence of periodontitis was defined according to the CDC/AAP periodontitis case definitions into no/mild, moderate, or severe periodontitis.[7] Severe periodontitis was defined as the presence of ≥2 interproximal sites with CAL ≥6 mm (not on the same tooth) and ≥1 interproximal site with PPD ≥5 mm. Moderate periodontitis was defined as having ≥2 interproximal sites with CAL ≥4 mm (not on the same tooth) or ≥2 interproximal sites with PPD ≥5 mm (not on the same tooth). No/mild periodontitis was defined as no evidence of moderate, or severe periodontitis.

Statistical analysis

A correlation between the PISA value and conventional periodontal parameters (mean PPD & mean CAL) were preliminarily explored using scatter plots. Subsequently, Pearson's coefficients of correlation were estimated. The reliability of PISA value for measuring periodontitis severity was assessed by comparing the continuous values of PISA among severity types of periodontitis defined by CDC/AAP and CPITN using either the one-way ANOVA or Kruskal-Wallis test. All statistical analyses were performed using STATA version 14.2. The p <0.05 was considered statistically significant.

Results

Baseline characteristics were demonstrated in Table 1. From a total of 2,643 EGAT employees who registered for the health survey in 2018 to 2019 and had completed periodontal examination, 69.4% were male. The mean age was 55.1±7.9 years with range of 34 to 74. Median of PISA value was 319.4 mm^2 with range of 2.2 to 3624.4 mm^2 and mean of PISA value was 440.68±415.40 mm^2. Defining periodontitis according to CPITN and CDC/AAP, the prevalence of severe periodontitis was 28.7% and 26.3%, respectively.

To explore correlation of PISA value with traditional periodontal parameters, scatter between PISA & mean PPD (Fig. 1a), and PISA & mean CAL (Fig. 1b) were plotted. Both had a trend of linear relationship with a positive slope. The Pearson's correlation was significant (p <0.001) with the coefficients of 0.78 and 0.52, respectively.

Level of PISA values among severity types of periodontitis were presented in Table 2. The results demonstrated that the median PISA value was the lowest in the no/mild group, and the highest value corresponded to the severe group. According to the CPITN classification, subjects had median PISA values of 118.99, 297.96, and 699.64 mm^2 for no/mild, moderate, and severe periodontitis, respectively. Similarly, when categorized based on CDC/AAP, subjects were categorized as having no/mild, moderate, and severe periodontitis, with median PISA values of 153.30, 285.12, and 710.91 mm^2, respectively. When comparing PISA values across severity, the PISA value increased corresponding to the periodontitis severity. There were statistically significant (p <0.001) differences of PISA value among severity levels of periodontitis classified by CPITN and CDC/AAP (Table 2). In addition, a dose-response relationship was also observed.

Table 1 *Baseline characteristics*

Characteristics	Frequency*	%
Age (years)**	**55.1±7.9**	
Sex		
- Male	1,835	69.4
- Female	808	30.6
PISA (mm^2)**	**440.7±415.4**	
CPITN		
- No/mild periodontitis	522	19.7
- Moderate periodontitis	1,363	51.6
- Severe periodontitis	758	28.7
CDC/AAP		
- No/mild periodontitis	444	16.8
- Moderate periodontitis	1,503	56.9
- Severe periodontitis	696	26.3

PISA, periodontal inflamed surface area
** Total number varied according to missing value.*
*** mean±SD*

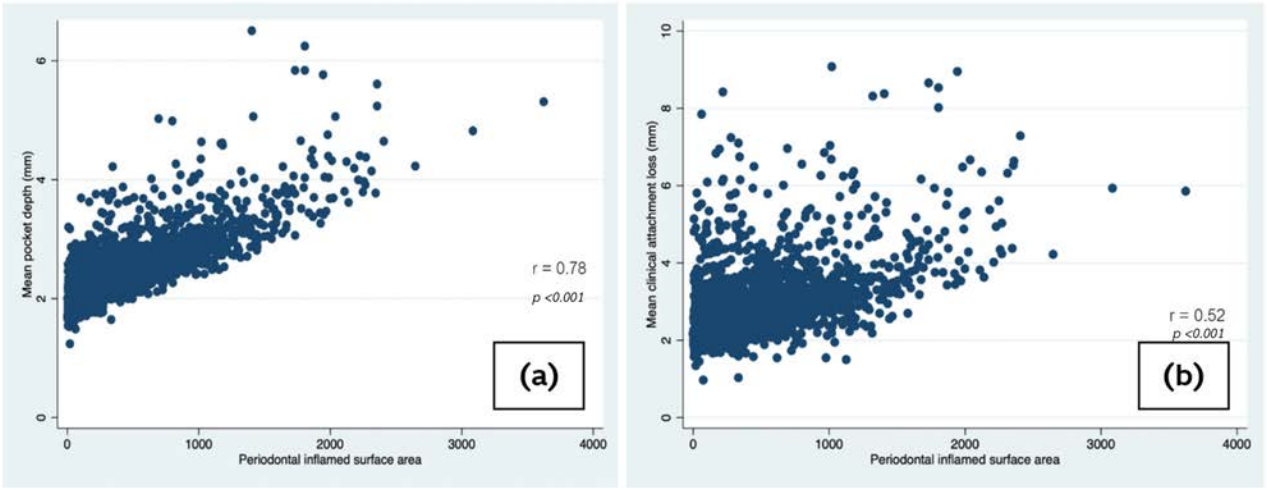

Figure 1 *Scatter plot (a) PISA & Mean PPD (b) PISA & Mean CAL*
PPD, probing pocket depth; CAL, clinical attachment level; r, Pearson Correlation coefficient

Table 2 *Comparison of PISA values among periodontitis severity*

		PISA (mm^2)				
	%	Mean±SD	Median	IQR	Minimum	Maximum
CPITN						
- No/mild	19.7	158.48±142.30	118.99[a]	177.79	4.38	1127.49
- Moderate	51.6	356.62±272.60	297.96[b]	363.27	2.19	1930.14
- Severe	28.7	786.18±517.15	699.64[c]	652.65	10.37	3624.36
CDC/AAP						
- No/mild	16.8	194.51±177.58	153.30[a]	194.38	4.38	1319.66
- Moderate	56.9	347.31±280.11	285.12[b]	365.97	2.19	1930.14
- Severe	26.3	799.37±529.04	710.91[c]	656.75	7.43	3624.36

PISA, periodontal inflamed surface area
Different letters indicate statistically significant differences (p <0.001)

Discussion

Our large cross-sectional study demonstrated the significant correlation between PISA value and conventional periodontal parameters (mean PPD & mean CAL). Additionally, when defining periodontitis using CPITN and CDC/AAP case definitions, the PISA value corresponded with periodontal disease severity. From here, it could imply that PISA is another periodontal parameter which is properly reliable for measuring current disease severity.

PPD and CAL are conventional periodontal parameters which are often used to measure disease severity,[2,3] but have limitations in measuring the level of periodontal inflammation. PPD is suitable for measuring current disease activity, for instance, the sites with deep PPD often accumulate a large amount of periodontal inflammation.[10] However, patients with pseudopocket, particularly in thick biotype, may have deepen PPD with less inflammation. While, CAL is a measurement representing cumulative disease destruction. Treated sites with resolved inflammation possibly exhibit high level of CAL with minimal inflammation.[7,11]

PISA is a promising periodontal parameter and has been increasingly utilized in various periodontal literature. The extent of periodontal inflammation is quantified in terms of the inflamed surface area, measured in square millimeters.[6] The surface area of pocket epithelium from each affected tooth will be meticulously estimated using complex geometry equations specified for individual tooth types.[12] Moreover, PISA takes into account not only PPD and CAL but also BOP as an indicator of ongoing inflammation.[9,13] By this concept, it provides quantitative measures that offer a more precise indication of the amount of periodontal inflammation.

In our study, Pearson's correlation with mean PPD and CAL were estimated. A significant positive correlation between PISA and both parameters were found. However, the coefficient of correlation between PISA and mean PPD was higher than that between PISA and mean CAL. This discrepancy might occur because PPD specifically represents the current disease activity, while CAL also includes the previously destructive periodontium, which is not related to the current inflammation. Moreover, an error could also contribute to inaccuracies in RE measurement.

Interestingly, a dose-response association between PISA value and the severity of periodontitis classified by CPITN and CDC/AAP were observed. Among our EGAT subjects, we found that the mean of PISA for the severe periodontitis by CDC/AAP was 799.37±529.04 mm^2, moderate periodontitis was 347.31±280.11 mm^2, and no/mild periodontitis was 194.51±177.58 mm^2. These findings were concordance with a previous study by Leira *et al,* which demonstrated sequential increase of average PISA values according to severity of periodontitis. However, their PISA values of each severity were higher than ours because they enrolled only 20 subjects per group and excluded individuals who had less than 15 remaining teeth.[14] Park *et al* also indicated the positive correlation of the PISA value with the CDC/AAP case definitions and the periodontal index.[15] Hence, it suggests that PISA is another periodontal parameter that can be relied upon for an accurate measurement of the present disease severity.

Theoretically, PISA is more suitable for quantification the actual amount of periodontal inflammation. Therefore, it usually employed in periodontal medicine to explore systemic health burden from periodontitis. Level of periodontitis-induced systemic inflammation should be correlated with the amount of existing periodontal inflammation.[16,17] Several studies showed that the high PISA level was related to increasing of systemic diseases prevalence and incidence such as cardiovascular disease (CVD)[18,19], hypertension (HT)[20], diabetes mellitus (DM)[21], and chronic kidney disease (CKD)[22]. PISA was also associated with increased circulating levels of systemic inflammation and endothelial dysfunction biomarkers including IL-6, pentraxin 3 (PTX3), soluble tumor necrosis factor-like weak inducer of apoptosis (sTWEAK), and amyloid-beta (Aβ) peptides (Aβ1-40).[18,19] Leira *et al* reported that the PISA value ≥727 mm^2 was an independent predictor of poor functional outcome of

lacunar infarct, after adjusting for clinical confounders.[23] For HT, Pietropaoli *et al* explored the relationship of periodontitis and blood pressure (BP) using mediation analysis with high C-reactive protein (CRP) as the mediator. Their results showed that mean systolic BP and diastolic BP were about 4 mmHg and 2 mmHg higher in the presence of severe BOP and PISA. Mediation analysis also revealed that the association between PISA value and uncontrolled BP was mediated by high-CRP of 5.4%.[20] Nesse *et al* found the dose-response relationship between HbA_1c and PISA value. Every 333 mm^2 -PISA-increase, HbA_1c would be increased by 1.0%.[21] Moreover, Iwasaki *et al* revealed that the highest PISA quartile was significantly associated with a greater cumulative incidence of decreased kidney function than the referent group, with an odds ratio of 2.24 after adjusting for covariates.[22]

In periodontal medicine research, PISA has been employed to quantify the amount of periodontal inflammation, as noted earlier. In clinical settings, PISA, which quantifies inflammation in terms of area units that patients can easily understand, can be utilized to simplify the communication of the systemic burden of periodontitis to patients. Moreover, it can also be used to concretely describe improvements after receiving periodontal treatments.

Although PISA provides a suitable measure of the inflammatory burden of periodontitis, integrating it into routine clinical practice presents significant challenges. These include the need for comprehensive records of PPD, CAL, and BOP. Additionally, examiners must input all relevant parameters into a specific spreadsheet, a procedure that is intricate and time-consuming. Moreover, the reliability of PISA may be compromised by potential measurement errors during multiple examinations, attributable to variables such as examiner technique, instrumentation, or tooth-specific characteristics. Another concern is that its calculation is based on the average anatomical human dentition, which does not account for individual variances in root lengths and surface areas that can significantly impact the assessment. Lastly, a critical limitation of the PISA approach is that the number of missing teeth directly influences the PISA estimation, potentially rendering it ineffective at discriminating between grades of periodontal severity.

The strength of this study was that the correlation between PISA and routine periodontal parameters/case definition was investigated in large scale of Thai population. The periodontal examination was performed with standard protocol, full-mouth examination with six sites per tooth, by the calibrated experienced periodontists. This study presents certain limitations. Primarily, the demographic profiles of our EGAT samples, predominantly middle-aged males with moderate to high socioeconomic status, may not be entirely representative of the Thai population. This could potentially impact oral health care and the severity of periodontal disease. Additionally, this research did not take into account other risk indicators of periodontitis, including smoking and systemic health conditions. The exclusion of these variables may limit the study's comprehensiveness in understanding the nature of PISA in some sub-cohorts.

Conclusion

In this large cross-sectional study, we found a significant correlation between PISA and conventional periodontal parameters. Additionally, we observed a dose-response relationship, indicating that PISA values increased with the severity of periodontitis, as classified by both CPITN and CDC/AAP case definitions. These findings suggested that, despite its limitations, PISA may provide a reliable assessment of ongoing periodontal inflammation and potentially reflect the severity of periodontal disease. Therefore, it is another parameter that could be used to assess periodontal health and its systemic implications.

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