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The association between interdental cleaning and periodontitis in an urban Thai adult cohort: a cross-sectional study

Panthira Aroonratana¹, Attawood Lertpimonchai^{1,2}, Lakshman Samaranayake^{1,3}, Prin Vathesatogkit⁴, Lalitsara Thienpramuk⁵ and Kanoknadda Tavedhikul^{1,2*}

Abstract

Background Plaque biofilm is a major etiologic factor of periodontitis, and its effective removal prevents or ameliorates the disease. However, toothbrushing alone does not sufficiently clean the interdental area, and additional interdental cleaning is required to completely remove the plaque from this locale. This cross-sectional study aimed to assess the association of interdental cleaning on the prevalence of periodontitis in a large urban Thai adult cohort.

Methods Interdental cleaning data were retrieved from a dental survey of 1,743 employees of the Electricity Generating Authority of Thailand (EGAT) in 2019. The Centers for Disease Control and Prevention/American Association of Periodontology (CDC/AAP) periodontal case definitions were applied. The participants were subdivided into two groups as those with or without periodontitis depending on their oral health status assessed by calibrated professional examiners. The proportion of subjects who performed interdental cleaning was assessed through a self-reported questionnaire by frequency (daily/ ≥ 1 per week/ none) and profile (correct/ incorrect) of interdental cleaning. Then, the association between interdental cleaning and periodontitis was calculated using logistic regression analysis controlling for the common risk factors of periodontitis such as age, sex, education, smoking, and diabetes.

Results Participants who performed interdental cleaning on a daily basis and ≥ 1 per week were 27.5% (95% CI: 25.4, 29.6) and 29.1% (95% CI: 27.0, 31.3), respectively while the remainder did not practice. Of those who used interdental cleaning, about one-half focused on sites with food impaction. There was a significant 44% lower prevalence of periodontitis (adjusted odds ratio of 0.56 (95%CI: 0.40, 0.79) in the cohort with a frequent and correct group.

Conclusions Our data indicate an inverse association between interdental cleaning and periodontitis, particularly in those who routinely adhered to it. Regular interdental cleaning is likely to have a salutary effect on oral health.

Trial registration The study was registered retrospectively in Thai Clinical Trials Registry, Registration number: TCTR20240817005, on 17 Aug 2024 (<https://www.thaiclinicaltrials.org>).

Keywords Dental floss, Interdental cleaning, Home care, Health behavior, Periodontitis

*Correspondence:

Kanoknadda Tavedhikul

kanok.kanok@gmail.com

Full list of author information is available at the end of the article



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Background

Periodontal disease is considered one of the most common diseases of the human kind with approximately 10% of the world population suffering from severe periodontitis at one time or another during their lifespan [1]. In Thailand, there is a high prevalence of periodontitis with 25.9% of adults and 36.3% of the elderly population afflicted, according to the most recent national oral health survey [2]. Periodontal disease in essence is a chronic multifactorial inflammatory disorder which affects tooth-supporting structures due to an imbalance of the host response and a dysbiotic plaque biofilm [3]. Periodontitis in particular is a major cause of tooth loss and affects masticatory function, esthetics, self-esteem, and quality of life. Moreover, the disease is closely associated with systemic health such as diabetes and atherosclerosis and is likely to impact a number of life course events [4].

It is widely accepted that plaque biofilm is a major etiologic factor of the disease, and its effective removal prevents or ameliorates periodontitis. Hence, routine mechanical plaque control by toothbrushing and interdental cleaning have been prescribed universally as the standard approaches for controlling plaque biofilm accumulation [5, 6]. A number of studies have shown that such adequate oral hygiene could minimize plaque deposition and, in turn, decrease the incidence of periodontitis and subsequent tooth loss [7, 8].

Owing to its anatomic profile, the interdental area of teeth is a common site of plaque biofilm accumulation and eventual periodontal breakdown. Toothbrushing does not sufficiently clean this area, and additional interdental cleaning is required to completely remove the plaque from this locale [9]. Unfortunately, patient compliance with interdental cleaning is generally quite low as indicated by data from several sources. For instance, only 9.3% of the surveyed population in a developed country such as Germany, reported daily flossing [10]. On the contrary, a recent national oral health survey in Thailand indicated that only 17.1% of adults have used interdental cleaning devices either occasionally or regularly [2]. The main obstacles for this low uptake appear to be poor awareness of its benefits, difficulty in adapting to the tedious technique, and the time-consuming nature of interdental cleaning [5, 11]. Despite the contention that interdental cleaning is important for maintaining good oral health, systematic reviews and meta-analyses of randomized controlled trials have noted only a relatively small reduction in periodontitis with routine interdental cleaning [5, 6, 9, 12, 13].

In Thailand as far as we are aware, there is little if any data from a large cohort on their interdental cleaning habits and its relationship to periodontitis. Hence,

the aim of the current investigation was to evaluate the association between interdental cleaning and periodontitis in an urban Thai adult population. For this purpose, we used data derived from a large longitudinal survey of urban workers at the Electricity Generating Authority of Thailand (EGAT). This is an ongoing project entailing medical and oral examination of over 1,700 adult Thai workers employed by the latter authority. It is conducted by trained and calibrated dental professionals of Chulalongkorn University, Faculty of Dentistry once every 5 years and hence the clinical data are reliable and trustworthy. For the purpose of our study we correlated the data on periodontitis from the foregoing EGAT study, with information collated from a response to a self-reported questionnaire survey on the interdental cleaning habits of the selected participants.

Materials and methods

Setting and study population

This cross-sectional study accessed and utilized the secondary data from the Electricity Generating Authority of Thailand (EGAT) project [14]. In particular, the data from the third survey (EGAT 3/3) subcohort data conducted in 2019 were used.

The inclusion criteria for the study were individuals who had registered and completed medical and periodontal examination, and periodontal self-reported questionnaire. The exclusion criteria were subjects with contraindications for periodontal examination including high-risk individuals for infective endocarditis, those who needed antibiotic prophylaxis before periodontal examination, and those who had < 2 remaining teeth. This study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2022–088).

Demographic data and general health

The demographic and health behavior data including age, sex, education, smoking, and diabetes were obtained from the EGAT3/3 database per the study needs.

Periodontal examination and periodontal case definitions

All periodontal examinations were performed by eight calibrated and trained periodontists of the Chulalongkorn University Faculty of Dentistry. The clinical examination comprised assessment of the number of remaining teeth, plaque score, bleeding on probing (BOP), periodontal probing depth (PPD), and gingival recession (RE). The PPD and RE were measured using a UNC-15 periodontal probe (Hu-Friedy, Chicago, IL, USA) at 6 sites per tooth (mesio-buccal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual, and disto-lingual). These measurements were made in millimeters and were rounded to

the nearest millimeter. Then, the clinical attachment level (CAL) was calculated from PPD and RE representing the distance from cemento-enamel junction (CEJ) to the base of the gingival sulcus. All teeth were examined except for the third molars and retained roots.

A total of eight periodontists who conducted the survey were calibrated with regard to periodontal measurements and indices, and consensus was reached. Accordingly, the weighted kappa (± 1 mm) coefficient of intra-examiner reliability on PPD and RE were 0.86–1.00 and 0.91–1.00, respectively, while the weighted kappa of inter-examiner reliability on PPD and RE were 0.74–1.00 and 0.72–1.00. The Centers of Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) case definitions were used as the basis of their periodontal disease classification respectively [15]. The periodontal status was categorized as those with, or without periodontitis; with the moderate and severe periodontitis groups were classified as the disease group and the remainder were categorized as the no/mild periodontitis group.

Self-reported questionnaire

The self-reported questionnaire on periodontal disease was divided into 3 domains: self-reported periodontal status, periodontal symptoms, and oral healthcare behavior (Supplementary Table 1). The details of the questionnaire's development and its validity testing were reported in a previous study of ours [16].

As mentioned above, relevant questions collected from previous studies were reviewed, revised, and translated into Thai language, and further developed. Their content validity was evaluated by a group of 7 periodontists focusing on relevance, comprehensibility, and comprehensiveness. All items on evaluation achieved a content validity index (CVI) score ≥ 0.86 based on expert agreement. A test–retest reliability evaluation was conducted with a group of 30 general patients, with Cohen's kappa coefficients ranging from 0.798 to 1.000, indicating reliability from substantial to almost perfect agreement. Subsequently, the questionnaire underwent pilot testing and was reassessed during the 2017 EGAT survey.

Each subject was interviewed individually by a trained dental assistant prior to periodontal examination. The examiners were completely blinded to the questionnaire responses.

Only the items related to oral health behavior (supplementary data, Domain C): were the focus of our study, The question on “How often do you use interdental cleaning?” (Q4) was used to estimate the frequency of interdental cleaning. Thus, an affirmative response to everyday use was categorized as a frequent user, the occasional user category was those who responded to use

interdental cleaning every week/month but not on a daily basis, and the remainder were categorized as non-users. In addition, the extent and profile of interdental cleaning were assessed through the following query “Which sites do you use the interdental cleaning?” (Q5). A positive response to the question of cleaning only when food gets stuck was categorized as an incorrect response that was ignored, while a response to the question on cleaning of all teeth or only interdental areas that are only accessible was considered as the correct response.

Statistical analysis

Data were analyzed using STATA statistical software, version 14.2. Descriptive statistics were applied to evaluate the participant characteristics. Continuous data were reported as means and standard deviations (SD), whereas categorical data were reported as frequencies and percentages. The prevalence of regular users and correct profiles of interdental cleaning were estimated, and a 95% confidence interval (95% CI) was obtained. The Chi-square test was used to calculate the relationship between those who performed interdental cleaning and age group, sex, and educational level. Then, to estimate the effect size of interdental cleaning, a multivariate logistic regression model was constructed using periodontitis as the outcome based on the CDC/AAP case definitions. Both the frequency and profile of interdental cleaning, either singly or in combination, were used as study factors. Odds ratios (ORs) and 95% CI were estimated and adjusted for conventional risk factors of periodontitis, including age, sex, education, smoking, and diabetes. A p -value < 0.05 was considered statistically significant. The Akaike's Information Criteria (AIC) and the Bayesian Information Criteria (BIC) were applied for model selection.

Results

A total of 1,743 participants out of 1,785 EGAT employees registered for the health survey in 2019 were included in the study. A total of the 42 individuals were excluded as they had less than two teeth.

The mean age of the selected cohort was 50.4 ± 6.9 years with 69% being males. Of these, over 80% had a bachelor's degree or a higher level of education; 30% were smokers, while the remainder were nonsmokers; and 10% reported having diabetes. On clinical examination, approximately 80% had periodontitis, of which 57% exhibited moderate disease, while the remaining 20% had severe periodontitis (Table 1).

As for interdental cleaning habits, 56.6% were frequent and occasional users (95% CI: 54.2, 58.9) (Table 2). In the item analysis, in all age groups over half of the participants (52.9–58.5%) were reported to be either frequent

Table 1 Demographic and dental characteristics of the study cohort

Characteristics	Number (%)
Age	
Less than < 40 yrs	140 (8.0)
From 41–60 yrs	1472 (84.5)
Over 61 yrs	131 (7.5)
Sex	
Female	541 (31.0)
Male	1202 (69.0)
Education	
Bachelor's degree or greater	1439 (82.6)
Diploma level	276 (15.8)
High school or lesser	28 (1.6)
Smoking	
Never	1213 (69.6)
Past	366 (21.0)
Current	164 (9.4)
Diabetes	
Non-diabetics	1565 (89.8)
Diabetics	178 (10.2)
Degree of Periodontitis	
No and Mild	412 (23.6)
Moderate	984 (56.5)
Severe	347 (19.9)

Table 2 Percentage and frequency of interdental cleaning in the study cohort

	N	Percent (95% CI)
Interdental cleaning (N = 1,743)		
No	757	43.4 (41.1, 45.8)
Yes	986	56.6 (54.2, 58.9)
Interdental cleaning frequency (N = 1,743)		
Never	757	43.4 (41.1, 45.8)
Occasional (≥ 1 times/weeks)	507	29.1 (27.0, 31.3)
Daily basis	479	27.5 (25.4, 29.6)
Interdental cleaning profile^a (N = 1,710)		
Never	757	44.3 (42.0, 46.7)
Incorrect	497	29.1 (26.9, 31.3)
Correct	456	26.7 (24.6, 28.8)
Combined interdental cleaning^a (N = 1,710)		
Never	757	44.3 (42.0, 46.7)
Occasional + Incorrect	312	18.3 (16.4, 20.2)
Occasional + Correct	167	9.8 (8.4, 11.3)
Frequent + Incorrect	185	10.8 (9.4, 12.4)
Frequent + Correct	289	16.9 (15.1, 18.8)

^a Missing data -33 subjects

or occasional interdental cleaners. In addition, female, and those with higher level of education were positively associated with interdental cleaning compared to their counterparts ($p < 0.05$; Fig. 1).

Of those who were interdental cleaners 27.5% performed the routine daily while 29.1% occasionally (≥ 1 time/week). Approximately 26% and 29% of the participants exhibited correct and incorrect profiles of interdental cleaning, respectively (Table 2). Among the participants who performed interdental cleaning, 52.2% limited their use to sites with food impaction. When the frequency and profile of interdental cleaning were consolidated, only 16.9% of the participants were frequent and correct users of interdental cleaning.

Univariate analysis revealed that interdental cleaning had a protective effect against periodontitis, with a significant crude ORs of 0.41–0.57 (Table 3). Other co-variables, including age, sex, education, smoking, and diabetes, were also significantly associated with periodontitis ($p < 0.05$). Periodontitis increased with age and was more pronounced in males. Participants with a higher educational level had a lower percentage of periodontitis. Smokers and diabetics were also found to have a higher prevalence of the disease.

Three final models were constructed based on the interdental cleaning criteria, i.e., *Model 1*, interdental cleaning frequency alone; *Model 2*, interdental cleaning profile alone; and *Model 3*, combination of models 1 and 2. After adjustment for all co-variables, there was a significant association between interdental cleaning and the prevalence of periodontitis in all models, with adjusted ORs of 0.55–0.66. In other words, performing interdental cleaning was associated with a 34–45% reduction in periodontitis (Table 4). When the AIC and BIC criteria were applied, Model 2 was the best fit (Supplementary Table 2).

Discussion

This is the first large cross-sectional survey conducted in Thailand to evaluate the association between interdental cleaning and periodontitis. Our findings clearly showed a modest association between interdental cleaning and a low prevalence of periodontitis in our urban Thai cohort which had a fairly good level of education. Furthermore, there was an association between age and sex with periodontitis as reported in many previous studies [17–19].

International data on the prevalence of interdental cleaning vary across studies. Our data indicate that the prevalence of Thais who performed interdental cleaning daily or at least once a week ranged from 27.5% to 29.1%. This contrasts with much higher prevalence rates of 60–70% of regular floss users, who spend at least once a week in the USA and Australia [20–22].

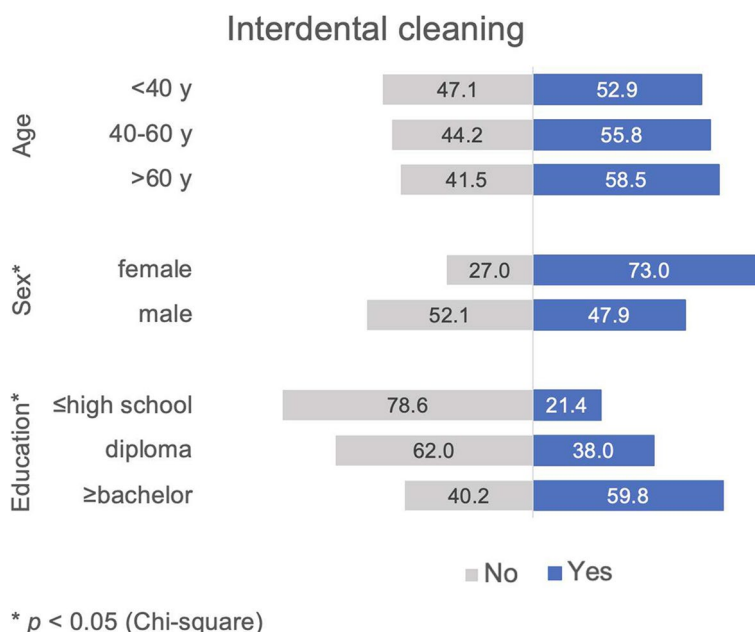


Fig. 1 Interdental cleaning prevalence

Nevertheless, in Korea and Brazil, this figure appears to be relatively low at 9–20% [23, 24], akin to our current findings. The latter figures are also closer to findings from a national health survey in Thailand conducted in 2017, where the prevalence of interdental cleaning among adults was only 17% and even lower than 6% in the elderly [2]. The discrepancy between the prevalence rates in the current and the latter findings in Thai populations is explicable in terms of the societal status of our cohort, who were educated, urban Thai with a moderate to high degree of socioeconomic status. It is reasonable to presume that the dental health awareness and affordability for oral health care of urbanites are higher than the average Thai adult population.

All previous self-reported studies considered only the frequency of cleaning. However, some individuals may floss or clean their teeth only at specific sites (e.g., areas with food impaction) and not routinely for removal of dental plaque for preventive purposes. Therefore, the cleaning profile appears to be as important as the frequency of interdental cleaning. This importance was further underscored by the AIC and BIC analyses. Consequently, we strongly recommend that both the frequency and profile of interdental cleaning be considered essential indices in all future studies. Neglecting either could lead to an incomplete understanding of their impact on oral health.

With respect to irregular interdental cleaners, we noted that more than half of the study population limited their cleaning to areas with food impaction only, suggesting

that a large number incorrectly followed the general oral hygiene recommendations. The current consensus recommendation for interdental cleaning frequency is once a day for all possible proximal areas [25]. Therefore, the incorrect behavioral patterns seen in the Thai cohorts should be rectified in the longer term through public dental health education programs as well as by demonstrations of proper oral hygiene routines and motivational activities when they visit their dentists.

Our study, based mainly on self-reported data on interdental cleaning, found a significant inverse association between interdental cleaning and periodontitis prevalence. These results are congruent with those of previous studies by Cepada et al., who evaluated data from the US National Health and Nutrition Examination Survey (NHANES) from 2011 to 2014 and noted an identical relationship. The odds ratio of periodontitis was 0.83 (95% CI: 0.72, 0.97) in highly frequent interdental cleaning users [20]. Another similar analysis in Australians performed by Crocombe et al., who evaluated data from the National Health Survey of Adult Oral Health in Australia (NSAOH) conducted from 2004 to 2006 found a lesser degree of periodontal pocket formation in regular interdental cleaners (prevalence ratios 0.61, 95% CI: 0.46, 0.82). However, the association between interdental cleaning and clinical attachment loss was not significant. The latter workers also contend that clinical attachment loss usually indicates a history of periodontal disease, and regular interdental cleaning may not necessarily minimize the risk of periodontitis in the long term [21]. Our

Table 3 Univariate analysis of independent variables and the risk of periodontitis

	Periodontitis (%)		Crude OR(95%CI)	p-value [†]
	No	Yes		
Age				<0.001
Less than 40 yrs	72 (51.4)	68 (48.6)	1	
From 40-60 yrs	325 (22.1)	1147 (77.9)	3.74 (2.62, 5.32)	
Over 61 yrs	15 (11.5)	116 (88.5)	8.19 (4.35, 15.40)	
Sex				<0.001
Female	214 (17.8)	343 (63.4)	1	
Male	214 (17.8)	988 (82.2)	2.67 (2.12, 3.35)	
Education				<0.001
Bachelor's degree or greater	380 (26.4)	1059 (73.6)	1	
Diploma	30 (10.9)	246 (89.1)	2.94 (1.98, 4.38)	
High school or lesser	2 (7.1)	26 (92.9)	4.66 (1.10, 19.75)	
Smoking				<0.001
Never	342 (28.2)	872 (71.2)	1	
Former	50 (13.7)	316 (86.3)	2.48 (1.80, 3.43)	
Current	20 (12.2)	144 (87.8)	2.83 (1.74, 4.59)	
Diabetes				<0.001
No	391 (25)	1174 (75)	1	
Yes	21 (11.8)	157 (88.2)	2.49 (1.56, 3.98)	
Interdental cleaning				<0.001
<i>Frequency</i>				
Never	126 (16.6)	631 (83.4)	1	
Occasional	140 (27.6)	367 (72.4)	0.52 (0.40, 0.69)	
Frequent	146 (30.5)	333 (69.5)	0.46 (0.35, 0.60)	
<i>Profile</i>				<0.001
Never	126 (16.6)	631 (83.4)	1	
Incorrect	136 (27.4)	361 (72.6)	0.53 (0.40, 0.70)	
Correct	145 (31.8)	311 (68.2)	0.43 (0.33, 0.56)	
<i>Combine</i>				<0.001
Never	126 (16.6)	631 (83.4)	1	
Occasional + Incorrect	81 (26)	231 (74)	0.57 (0.42, 0.78)	
Occasional + Correct	55 (32.9)	112 (67.1)	0.41 (0.28, 0.59)	
Frequent + Incorrect	55 (29.7)	130 (70.3)	0.47 (0.33, 0.68)	
Frequent + Correct	90 (31.1)	199 (68.9)	0.44 (0.32, 0.60)	

[†] Chi-square test

findings partially agree with the latter workers [21], as we noted that frequent and occasional users were positively associated with a lower degree of periodontal disease.

Based on experimental gingivitis studies [26], dental plaque has been identified as the primary cause of gingivitis. The accumulation of biofilm promotes periodontal inflammation. While not all cases of gingivitis progress to periodontitis, gingivitis is recognized as an important precursor to periodontitis [27]. Regular and correct use of interdental cleaning methods effectively controls the amount of dental plaque in frail interproximal areas.

Thus, the progression of gingival inflammation is limited, and periodontitis can be prevented.

The overall and long-term oral health benefits of interdental cleaning remain controversial. The studies evaluated to date have been few and often short-term, unreliable, and low quality, with small sample sizes and therefore with questionable assessment of potential long-term benefits. This issue was hotly debated recently in both the public and professional arenas in the USA and UK, eventually concluding that the net benefit and efficacy of interdental cleaning are questionable [5, 12, 13].

Table 4 Multivariate logistic regression analysis

Factors	Adjusted OR ^a (95% CI)
Interdental cleaning	
<i>Frequency</i>	
Never users	1
Occasional users	0.65 (0.48, 0.87)
Frequent users	0.56 (0.42, 0.76)
<i>Profile</i>	
Never users	1
Incorrect users	0.62 (0.46, 0.83)
Correct users	0.57 (0.42, 0.77)
<i>Combine</i>	
Never	1
Occasional + Incorrect	0.66 (0.47, 0.93)
Occasional + Correct	0.57 (0.38, 0.86)
Frequent + Incorrect	0.55 (0.37, 0.82)
Frequent + Correct	0.56 (0.40, 0.79)

^a Adjusting with age, sex, educational level, smoking and diabetes

Our study is unique for Thailand in many respects, as it is the first in a Thai population to assess the proportion of regular/correct interdental cleaners as well as the association between interdental cleaning and periodontitis. All the participants underwent periodontal examination by trained and calibrated periodontists and a self-reported questionnaire on dental health was administered through interviews in the native language by trained personnel.

Additionally, we categorized periodontal status using the CDC/AAP case definitions, which are often preferred in epidemiological studies for their high specificity, especially in identifying severe cases. It is known that such categorization facilitates effective surveillance and supports population-based research efforts [15]. Indeed, Morales et al., have recently compared the reliability of CDC/AAP classification with the AAP/EFP classification, and stated that the latter is likely to be less accurate in epidemiological studies of adult populations [28]. We also performed a sensitivity analysis to compare the new AAP/EFP classification with the CDC/AAP classification. Our results also demonstrated a significant effect of interdental cleaning on periodontal health, showing a similar pattern across all three multivariate models (Supplementary Table 3), i.e., the choice of classification system had no significant effect on the outcomes we reported.

In our investigation, several inherent weaknesses were identified. First, our reliance on patient-reported historical data introduces potential biases, notably recall bias, which can either inflate or deflate expected outcomes or associations. To address this concern, future studies should reduce the recall period to mitigate this bias

effectively. Moreover, researchers could enhance the assessment of oral health behaviors by having participants demonstrate their interdental cleaning habits or perform oral hygiene routine habits. This approach could yield more objective and reliable data for analysis. Additionally, it is crucial to account for the impact of social desirability on the anticipated outcome during the planning stage of data collection. Therefore, incorporating measurement scales such as Marlowe-Crowne Social Desirability Scale or Martin-Larsen Approval Motivation Score can aid in identifying and quantifying the social desirability aspect within self-reported information [29].

Next, due to the cross-sectional nature of the study a causal relationship between interdental cleaning and periodontitis, if any, can not be established from our findings. Above all, the study cohort does not represent the general Thai population as they had an above average education and relatively high socioeconomic status. Moreover, our participants were predominantly in older age group. As age is a non-modifiable factor for periodontitis, the prevalence and severity of the disease increase with age [30].

A final concern was that most of the participants were male. It has been recognized that males have a significantly higher prevalence, extent and severity of periodontal disease than females, due their lifestyles e.g., lower rates of dental visits, poorer oral hygiene practices, and higher smoking rates which may contribute to the disparities in periodontal disease observed [31]. The predominance of older male participants limits the generalizability of the results, particularly to younger individuals or females resulting in overestimation of the prevalence and severity of periodontal disease.

Despite the foregoing considerations our data indicate that regular interdental cleaning can positively impact the oral health of Thais. Therefore, Thai health authorities should contemplate integration of interdental cleaning into public health strategies. This can be achieved through conducting health promotion campaigns, incorporating into school health programs, encouraging dental professionals to prioritize the importance of interdental cleaning in their practice and developing policies and guidelines for it as a standard recommendation. These efforts have the potential to standardize care practices, increase widespread acceptance, enhance overall oral health, lower dental treatment expenses, and improved general health outcomes.

Conclusions

This study indicated that a low proportion of educated Thai adults with a relatively high socioeconomic status frequently and correctly practiced good interdental cleaning. The effect of such interdental cleaning habits

was found to be salutary and, in general, associated with good periodontal health. We believe that further efforts should be made to motivate the Thai population to practice good oral hygiene habits, including regular interdental cleaning and a correct technique.

Abbreviations

EGAT	The Electricity Generating Authority of Thailand
CDC/AAP	The Centers for Disease Control and Prevention/American Association of Periodontology
BOP	Bleeding on probing
PPD	Periodontal probing depth
RE	Gingival recession
CAL	Clinical attachment level
CEJ	Cemento-enamel junction
95% CI	95% Confidence interval
AIC	Akaike's Information Criteria
BIC	Bayesian Information Criteria
NHANES	The US National Health and Nutrition Examination Survey
NSAOH	The National Health Survey of Adult Oral Health in Australia
AAP/EFPP	American Association of Periodontology/ European Federation of Periodontology

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12903-024-04980-6>.

Supplementary Material 1.

Acknowledgements

We would like to express our gratitude to the medical staff of Ramathibodi Hospital, as well as the staff and residents of the Graduate Periodontics Program at Chulalongkorn University, for their support in collecting medical and dental data. Special thanks are extended to Nisakorn Thongmung for organizing the survey and managing the medical data. L.S. was supported by the Chulalongkorn University, second century (C2) high potential professoriate fund at its Faculty of Dentistry

Authors' contributions

P.A., A.L. and K.T. contributed to the study conception and design. Material preparation, data collection and analysis were performed by P.A., A.L. and K.T. The first draft of the manuscript was written by P.A., A.L. and K.T. L.S. fully revised and edited the manuscript. All authors read and approved the final manuscript.

Funding

None.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to involved patient privacy but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (HREC-DCU 2022–088). Informed consent was obtained from all participants. All the collected data were anonymized and securely stored to ensure the privacy and confidentiality of the participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Periodontology, Faculty of Dentistry, Chulalongkorn University, 34 Henri Dunant Rd., Wangmai, Patumwan, Bangkok 10330, Thailand. ²Center of Excellence in Periodontal Disease and Dental Implant, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. ³Faculty of Dentistry, University of Hong Kong, Hong Kong, Hong Kong. ⁴Division of Cardiology, Department of Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand. ⁵Medical and Health Division, Electricity Generating Authority of Thailand, Nonthaburi, Thailand.

Received: 31 July 2024 Accepted: 30 September 2024

Published online: 05 October 2024

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