

The Effect of Cigarette Smoking on the Severity of Periodontal Disease Among Older Thai Adults

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Background: The aim of this study is to determine the effect of cigarette smoking on the severity of periodontitis in a cross-sectional study of older Thai adults.

Methods: The study population consisted of 1,960 subjects (age 50 to 73 years old). All subjects received both medical and dental examinations. Periodontal examinations, including plaque score, probing depth, and clinical attachment level, were done on all teeth present in two diagonal quadrants. Sociodemographic characteristics and smoking status were obtained by questionnaires. Multinomial logistic regression was used to address the association between cigarette consumption and mean clinical attachment level.

Results: In this study population, 48.7% were non-smokers, 14.4% were current smokers, and 36.9% were former smokers. Current smokers had higher percentage of sites with plaque, deeper mean probing depth, and greater mean clinical attachment level than former smokers and non-smokers. The odds of having moderate and severe periodontitis for current smokers were 1.7 and 4.8 times greater than non-smokers, respectively. Former smokers were 1.8 times more likely than non-smokers to have severe periodontitis. Quitting smoking reduced the odds of having periodontitis. For light smokers (<15 packyear), the odds for severe periodontitis reverted to the level of non-smokers when they had quit smoking for ≥10 years. For moderate and heavy smokers (≥15 packyear), the odds of having severe periodontitis did not differ from those of non-smokers when they had quit smoking for ≥20 years.

Conclusions: There was a strong association between cigarette smoking and the risk of periodontitis among older Thai adults. Quitting smoking appears to be beneficial to periodontal health. *J Periodontol* 2005;76:566-572.

KEY WORDS

Age factors; periodontal attachment loss/etiology; risk factors; smoking/adverse effects; smoking cessation; Thailand.

Evidence suggests that cigarette smoking is a major risk factor of periodontal disease. Subjects who smoked had deeper probing depths (PD), more attachment loss, and more alveolar bone loss than subjects who did not smoke.¹⁻⁴ Cigarette smoking also affects disease progression. In longitudinal studies, smokers developed more sites with increased PD and alveolar bone loss.⁵⁻⁷ In addition, responses to periodontal treatment, both non-surgical and surgical, appear to be compromised.⁸⁻¹⁰ Treatments in smokers resulted in lesser probing depth reduction and smaller clinical attachment level (CAL) gain. Moreover, smokers were at a higher risk for recurrent diseases during periodontal maintenance care than non-smokers.¹¹

Although effects of cigarette smoking on the periodontium have been extensively examined, most studies compared the risk of different smoking status; i.e., current smokers, former smokers, non-smokers, on the severity or progression of periodontal disease. Few epidemiological studies have addressed the effect of smoking dose and the past effect of smoking among former smokers.^{2,4,12} It is the purpose of this study to determine the effect of cigarette smoking on periodontal health in a cross-sectional study of older Thai adults. We used a multinomial logistic regression model to investigate the association between the level of cigarette consumption and periodontal attachment loss, taking into account the

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effect of age, gender, education, oral hygiene, and diabetes mellitus. In addition, we examined the effect of previous cigarette consumption and the number of years since quitting smoking on the severity of periodontitis among former smokers.

MATERIALS AND METHODS

Study Population

The study population consisted of senior employees and retired personnel of the Electrical Generating Authority of Thailand (EGAT). This study is part of a longitudinal study that has been conducted to identify causes of death among these individuals since 1985.¹³ All participants received both medical and dental examinations. Sociodemographic characteristics, health behavior, and a detailed medical history were obtained by a questionnaire and an interview. Of 2,276 subjects examined, a total of 1,960 participants with complete data on all covariates were included for analysis. This study was approved by the Ethical Review Committee of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand.

Periodontal Examinations

One maxillary and one contralateral mandibular quadrant were randomly selected. All teeth in these quadrants were examined, except third molars and retained roots. Individuals with fewer than six teeth in the two selected quadrants were excluded.¹⁴ Periodontal examinations included the number of missing teeth, plaque score, PD, and gingival recession. Probing depth and gingival recession were measured on six sites per tooth. Clinical attachment level was calculated as the sum of PD and gingival recession.

Smoking Status Assessment

Smoking status was assessed by a self-reported questionnaire. Participants were asked to estimate the number of cigarettes consumed per day and the number of years they smoked. Smokers were defined as persons who had smoked at least 100 cigarettes in their lifetime. Current smokers were persons who were smoking at the time of examination. Former smokers were persons who had quit smoking at the time of examination. Former smokers were also asked to report the age when they quit smoking. Years since quitting smoking was calculated by subtracting the age when quitting smoking from the age of the individual calculated at the end of examination year (2002). Smoking exposure was expressed in term of packyear (pkyr), which is calculated by the multiplication of the number of packs of cigarettes smoked per day by the number of years smoked.

Statistical Analysis

Subjects were categorized according to smoking status into current smokers, former smokers, and non-smokers.

Clinical variables including mean age, mean plaque score, mean PD, mean CAL, amount of cigarette consumption, percentage of sites with PD ≥ 5 mm, and percentage of sites with CAL ≥ 5 mm were computed for each subject and then averaged across subjects into the three groups. For variables with equal variances among groups, the significant difference between groups was tested by means of analysis of variance (ANOVA) and post hoc multiple comparisons using the Bonferroni test. For variables with unequal variances among groups, the significance of differences between groups was tested using Welch test and post hoc multiple comparisons were performed according to the Tamhane test.

Multinomial logistic regression was used to address the association between the level of cigarette consumption and mean CAL. For the former smoker group, the relationship between previous cigarette consumption, years since quitting, and mean CAL was assessed. The dependent variable was mean clinical attachment level. We chose mean CAL to represent the severity of periodontitis in a given patient since it is a cumulative result of previous periodontal destruction. Mean CAL was stratified into three groups: <2.5 mm, mild; 2.5 to 3.9 mm, moderate; and ≥ 4 mm, severe periodontitis. In the multinomial logistic regression analysis, the CAL <2.5 mm group (mild periodontitis) served as the reference group for all comparisons. We included the variables of age, gender, plaque score, education, and diabetes status in all multivariate models. Age and plaque score were included as continuous variables. Education was defined as less than or equal to high school level and higher than high school level. Presence or absence of diabetes was determined by fasting blood sugar of ≥ 126 mg/dl or taking medications versus fasting blood sugar of <126 mg/dl. The effect of age, gender, plaque, education, and diabetes status on the severity of periodontitis in this study population was described previously.¹⁵ A software package^{||} was used for all calculations and analyses. Statistical significance was determined at $\alpha = 0.05$.

RESULTS

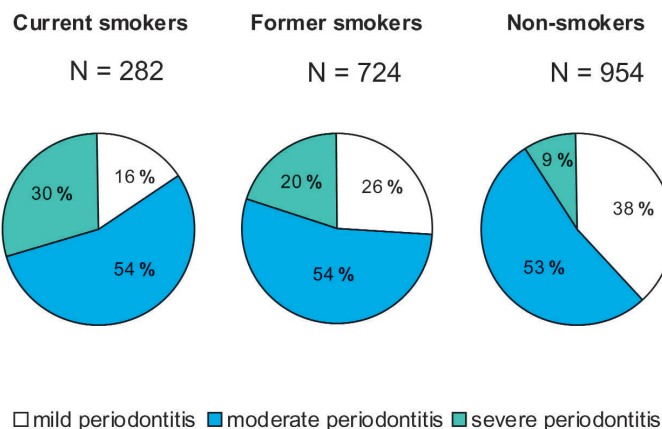
The demographic characteristics and periodontal status of the study subjects are depicted in Table 1. Among current smokers, the proportion of light (<15 pkyr), moderate (15 to 29.9 pkyr) and heavy smokers (≥ 30 pkyr) were 38.7%, 37.2%, and 24.1%, respectively. Nearly three-quarters (74.4%) of the former smokers had quit 10 or more years earlier (average 18.0 ± 10.6 years).

Periodontal variables were assessed according to smoking status (Table 2). Current smokers had higher percentage of sites with plaque, deeper mean probing depth, and greater mean clinical attachment level than

|| SPSS Version 11.0, SPSS, Inc., Chicago, IL.

Table 1.**Demographic Characteristics of the Study Population (N: 1,960)**

Characteristic	N (%)
Age (years)	
<60 (range 50-59)	1,200 (61.2)
≥60 (range 60-73)	760 (38.8)
Gender	
Male	1,463 (74.6)
Female	497 (25.4)
Smoking status	
Current smokers	
<15 pkyr	109 (5.5)
15-29.9 pkyr	105 (5.4)
≥30 pkyr	68 (3.5)
All	282 (14.4)
Former smokers	
<15 pkyr since quitting	
<10 years	82 (4.2)
10-19.9 years	136 (6.9)
≥20 years	249 (12.7)
All	467 (23.8)
≥15 pkyr years since quitting	
<10 years	103 (5.3)
10-19.9 years	108 (5.5)
≥20 years	46 (2.3)
All	257 (13.1)
Non-smokers	954 (48.7)
Mean CAL (mm)	
<2.5 (mild)	597 (30.4)
2.5-3.9 (moderate)	1,050 (53.6)
≥4 (severe)	313 (16.0)

**Figure 1.**

The proportion of subjects with mild, moderate, or severe periodontitis within each smoking group.

former smokers and non-smokers. The values for former smokers were in between those of current smokers and non-smokers. The difference between all pairs of smoking groups, including current smokers versus former smokers, current smokers versus non-smokers, former smokers versus non-smokers, was statistically significant. Similar findings hold true for the percentage of sites with PD ≥5 mm and CAL ≥5 mm.

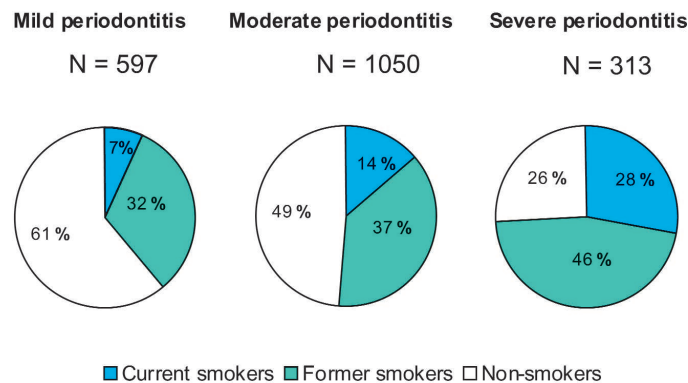
The proportion of subjects with mild, moderate, and severe periodontitis within each smoking group was assessed. We found a similar proportion of subjects with moderate periodontitis in all smoking groups. However, the proportion of subjects with mild and severe periodontitis in each smoking group varied (Fig. 1). Non-smokers had the highest proportions of subjects with mild periodontitis (38%) and the lowest proportions of subjects with severe periodontitis (9%). Conversely, current smokers had the lowest proportions of subjects with mild periodontitis (16%) and the highest proportion of subjects with severe periodontitis (30%). The values for former smokers were in between those of current smokers and non-smokers. We also determined the distribution of current smokers, former smokers, and non-smokers within each periodontitis group (Fig. 2). The percentage of current smokers in the mild periodontitis group was 7%. The value increased to 14% and 28% in moderate periodontitis and severe periodontitis groups, respectively. In contrast, the percentage of non-smokers decreased as the severity of periodontitis increased. In addition, we found a positive correlation between the level of cigarette consumption and the severity of periodontitis. Mean cigarette consumption for subjects with severe, moderate, and mild periodontitis was 12.2, 7.7, and 4.5 pkyr,

Table 2.**Periodontal Variables According to Smoking Status (Mean ± SD)**

Variable	Current Smokers	Former Smokers	Non-Smokers	Total
Plaque score (%) [*]	66.3 ± 24.6	62.2 ± 22.9	58.1 ± 23.6	60.8 ± 23.7
Mean PD (mm) [†]	2.8 ± 0.8	2.5 ± 0.7	2.3 ± 0.6	2.4 ± 0.7
Mean CAL (mm) [†]	3.7 ± 1.4	3.3 ± 1.1	2.8 ± 0.9	3.1 ± 1.1
Sites with PD ≥5 mm (%) [†]	10.4 ± 13.9	6.8 ± 11.6	4.0 ± 8.1	6.0 ± 10.7
Sites with AL ≥5 mm (%) [†]	26.0 ± 25.2	18.0 ± 20.9	11.1 ± 14.7	15.8 ± 19.6

^{*} Significant difference between all pairs of smoking groups at $P < 0.05$, using ANOVA and Bonferroni post hoc analysis.

[†] Significant difference between all pairs of smoking groups at $P < 0.001$, using Welch test and Tamhane post hoc analysis.

**Figure 2.**

The proportion of subjects who were current smokers, former smokers, or non-smokers within each periodontitis group.

Table 3.

Adjusted Odds Ratios According to Smoking Status and Level of Cigarette Consumption

Smoking Status	Adjusted OR	95% CI	P Value
Severe periodontitis			
Current smokers			
<15 pkyr	4.2	2.1-8.2	<0.001
15-29.9 pkyr	4.3	2.1-8.9	<0.001
≥30 pkyr	7.9	3.0-20.8	<0.001
All	4.8	2.9-7.9	<0.001
Former smokers	1.8	1.2-2.7	0.003
Non-smokers	1.0*		
Moderate periodontitis			
Current smokers			
<15 pkyr	1.4	0.8-2.3	0.282
15-29.9 pkyr	1.6	0.9-3.0	0.109
≥30 pkyr	2.9	1.2-6.7	0.014
All	1.7	1.1-2.5	0.009
Former smokers	1.0	0.7-1.2	0.717
Non-smokers	1.0*		

Odds ratios and their 95% confidence intervals (95% CI) are from multinomial logistic regression analysis and are adjusted for age, gender, plaque score, education, and diabetes status.

* Reference group.

respectively. The mean difference between each pair of groups was statistically significant ($P < 0.001$, Welch test and Tamhane post hoc analysis).

The degree of association between the level of cigarette consumption and the risk for moderate and severe periodontitis was investigated using the multinomial logistic regression analysis. Factors known to affect the severity of periodontitis, including age, gender, plaque score, education, and diabetes status were included in the model. Both current smokers and former smokers had an increased risk for severe periodontitis, compared to non-smokers (Table 3). The odds

Table 4.

Adjusted Odds Ratio for Periodontitis Among Former Smokers According to Previous Cigarette Consumption and Years Since Quitting

Previous Cigarette Consumption	Years Since Quitting	Adjusted OR	95% CI	P Value
Severe periodontitis				
<15 pkyr	<10	2.8	1.3-5.6	0.005
	10-19.9	1.9	1.0-3.6	0.061
	≥20	1.0	0.6-1.6	0.862
	All	1.4	0.9-2.2	0.096
≥15 pkyr	<10	4.1	1.9-8.7	<0.001
	10-19.9	2.6	1.2-5.3	0.011
	≥20	2.0	0.8-4.8	0.145
	All	2.9	1.7-4.9	<0.001
Moderate periodontitis				
<15 pkyr	<10	0.9	0.5-1.6	0.622
	10-19.9	1.2	0.7-1.8	0.527
	≥20	0.7	0.5-0.9	0.014
	All	0.8	0.6-1.1	0.132
≥15 pkyr	<10	1.9	1.0-3.5	0.038
	10-19.9	1.5	0.9-2.7	0.133
	≥20	0.7	0.3-1.5	0.370
	All	1.4	1.0-2.1	0.070

Odds ratios and their 95% confidence intervals (95% CI) are from multinomial logistic regression analysis and are adjusted for age, gender, plaque score, education, and diabetes status. Non-smokers are the reference group.

ratio was higher among current smokers than former smokers. Among current smokers, the odds of having severe periodontitis increased with the amount of cigarette consumption. The odds ratio for light, moderate and heavy smokers was 4.2, 4.3, and 7.9, respectively. Only current smokers who were heavy smokers had an increased risk of moderate periodontitis. Current smokers who were moderate and light smokers as well as former smokers were not at a higher risk for moderate periodontitis.

Among former smokers, the effect of previous cigarette consumption and years since quitting on the risk for moderate and severe periodontitis was examined. To allow sufficient number of subjects within each subgroup for statistical analysis, previous cigarette consumption was reclassified into just two groups: <15 pkyr (light) and ≥15 pkyr (moderate and heavy). Years since quitting was stratified into three groups: <10 years, 10 to 19.9 years, ≥20 years. Overall, the risk for periodontitis decreased as the amount of previous cigarette consumption decreased and the number of years since quitting increased (Table 4). Former light smokers were not at a greater risk for moderate periodontitis and only those who quit smoking <10 years were at a higher risk for severe periodontitis, with an

odds ratio of 2.8. Former moderate and heavy smokers were 2.9 times more likely to have severe periodontitis than non-smokers and only those who quit smoking <10 years were at a greater risk for moderate periodontitis. The odds of having moderate periodontitis among moderate and heavy smokers was not different from the level of non-smokers when they quit smoking ≥ 10 years whereas the odds of having severe periodontitis was not different from that of non-smokers when they quit smoking ≥ 20 years.

DISCUSSION

The purpose of this study is to investigate the effect of cigarette smoking on the severity of periodontitis among a group of older Thai adults. The results from this study, in accordance with numerous publications from various populations, showed the adverse effect of smoking on periodontium, in terms of increased periodontal attachment loss and increased probing depth.^{2,4,5,7,16,17} We also observed the dose-effect relationship between the level of cigarette consumption and the odds of having moderate and severe periodontitis. In addition, we showed that previous cigarette consumption and years since quitting affected the risk of periodontitis among former smokers.

In this study, we evaluated various aspects of periodontal status. The extent of disease was determined by the percentage of sites with PD ≥ 5 mm and the percentage of sites with CAL ≥ 5 mm. The overall severity of disease was assessed by mean probing depth and mean clinical attachment level. We found that current smokers had the greatest extent and severity of disease. The periodontal status of former smokers was somewhat between that of current smokers and non-smokers. The findings are consistent with those previously reported.¹⁸⁻²² The increase in mean CAL among smokers was significant. We found that the difference in mean CAL between current smokers and non-smokers was 0.9 mm. Axelsson et al. reported the difference of 0.85 to 0.88 mm in a comparable age group (age range 50 to 74 years old).²² Haffajee and Socransky reported the difference of 0.73 mm in a group with mean age of 46 years old.²³ Mean annual attachment loss within treated and untreated subjects that has been reported ranged between 0.1 to 0.3 mm.^{24,25} Therefore, it appears that the disease progression among smokers is approximately 3 to 9 years faster than that of non-smokers.

To assess the prevalence of periodontitis in each smoking group, we categorized the subjects by mean clinical attachment level into mild, moderate, and severe periodontitis. The prevalence of severe periodontitis in current smokers and former smokers was approximately three times and two times higher than that of non-smokers, respectively. In addition, within each periodontitis group, the proportion of current

smokers was increased as the severity of periodontitis increased. There was also a positive correlation between the level of cigarette consumption and the severity of periodontitis. The more cigarette consumption (in terms of pkyr), the worse periodontal condition was observed. Taken together, the findings strongly suggested that cigarette smoking was related to more severe periodontitis.

In this study, the plaque score among current smokers was the highest, as compared to former smokers and non-smokers. However, using multinomial logistic regression analysis, we showed that the risk of having periodontitis was still greater among smokers after adjustment for plaque score. In earlier studies, the adverse effect of smoking on periodontal tissues had been obscured by the parallel findings of smoking and poor oral hygiene.^{26,27} At present, it is well established that poorer oral hygiene among smokers cannot solely explain their poorer periodontal health. This notion was further confirmed in a longitudinal study conducted in a population of professional musicians with high standard of oral hygiene.⁶ The overall plaque score of these subjects was 0.8, using the plaque index system of Silness and L  e.²⁸ Even with good plaque control, smokers showed increased frequency of diseased sites and more loss of alveolar bone height, as compared to non-smokers whose periodontal conditions remained stable throughout the 10-year study period.

We used multinomial logistic regression analysis to estimate the odds of periodontitis among smokers. Mean clinical attachment level was chosen as a main outcome variable since it represented cumulative periodontal destruction over time.²⁴ Mean CAL was obtained from half mouth examinations at six sites per tooth of all teeth present except third molars and retained roots. Although whole mouth examination is currently considered the gold standard, it is very costly and time-consuming, especially for epidemiological studies with a large sample size. In most epidemiological studies, periodontal examinations were conducted on selected teeth and at selected sites, which may underestimate the prevalence and extent of the disease. It has been shown that half-mouth assessment was an appropriate alternative to whole-mouth assessment.²⁹ The intraclass correlation coefficient between half mouth assessment and whole mouth assessment for mean probing depth, mean clinical attachment level, and percentage of sites above a specified threshold were generally greater than 0.90. Therefore, the data on probing depth and clinical attachment level in this study are likely to represent the true severity of periodontitis in the individual. In this multinomial logistic regression model, the odds ratio for moderate and severe periodontitis was assessed according to smoking status. Several factors (age, gender, plaque score, education, and diabetes status) known to affect periodontal disease severity were included

and adjusted for in the model. It is important to note that the mild periodontitis group was used as a reference group (CAL 1.4 to 2.4 mm) for the calculation of odds ratio for moderate and severe periodontitis. The minimum mean clinical attachment level in the reference group was quite high, probably due to the older age of study subjects. By using this group as the reference, we may underestimate the odds ratio for moderate and severe periodontitis.

The risk estimate for the association between periodontal diseases and cigarette smoking varies widely among studies. Assessment of risk showed that smokers were associated with 1.4 to 11.8 fold increase in risk for having periodontitis compared to non-smokers.^{2,4,7,17,21,30-34} This could be due to the difference in case definitions for periodontitis and smoking status. It was shown that the disease definition had an impact on the prevalence, and the relative risk varied as a function of the prevalence. A narrow definition will result in a low prevalence and a high risk, whereas a broader definition will result in a higher prevalence and a lower risk.³⁴ In this study, the odds of having severe periodontitis among current smokers and former smokers was 4.8 and 1.8, respectively. When the level of cigarette consumption is considered, the dose-dependent effect of smoking on the odds of having periodontitis is observed.^{1,2,19,20} We found that the odds for having severe periodontitis was increased from 4.2 among light smokers to 7.9 among heavy smokers.

Smoking cessation appears to be beneficial for periodontal health. A long-term prospective study showed that periodontal bone height and frequency of diseased sites (PD \geq 4 mm) remained stable among non-smokers and smokers who quit before the baseline examination but became worse among subjects who continued to smoke.⁶ Many cross-sectional studies also showed that former smokers had less alveolar bone loss and attachment loss than current smokers.^{2,4,19,20,23,35} The prevalence of moderate and severe periodontitis was also lower in former smokers, compared to current smokers.¹⁸ Similar findings were observed in our study. However, it is still unclear how long after smoking cessation benefits can be observed.

In this study, we showed that the odds of having severe periodontitis in light smokers (<15 pkyr) were not different from that of non-smokers when they had quit smoking \geq 10 years. For moderate and heavy smokers (\geq 15 pkyr), the odds for moderate and severe periodontitis reverted to the level of non-smokers when they quit \geq 10 years and \geq 20 years, respectively. Tomar and Asma reported that the odds of periodontitis for former smokers who quit \geq 11 years were indistinguishable from non-smokers.⁴ In their study, periodontitis was defined as the presence of one or more sites that had both probing depth and attachment loss

of \geq 4 mm and former smokers were subjects who had smoked \geq 100 cigarettes in their lifetime and were not currently smoking. Although, it is quite difficult to compare the result between studies due to different case definitions, it is clear that quitting smoking reduces the odds of having periodontitis and the odds were inversely related with the number of years since quitting smoking. Longitudinal studies are needed to directly estimate the change in risk of periodontitis after quitting smoking.

Tobacco consumption is one of the most significant risk factors on general health among the Thai population.^{13,36} The national smoking survey (year 2001) reported that the prevalence of smokers among the Thai population was 26.2% for 25 to 59 year olds, and 21.1% for those \geq 60 years old.³⁷ In this study, the prevalence of smokers was 16.3% for the 50- to 59-year-old group, and 11.4% for those \geq 60 years old. Data on the prevalence of smokers within this study population in the years 1985 and 1997 were available.¹³ The overall proportion of smokers was 50.0%, 31.0%, and 14.4% in the years 1985, 1997, and 2002, respectively. The decline in the prevalence of smokers may be due partly to increasing health awareness as they participated in the study. To our knowledge, this is the first study that examined the effect of smoking on periodontal health in a large group of Thai people. In addition, various demographic and medical data were available which allowed adjustment for possible confounders. Despite the limitations of the study, including its cross-sectional design and the non-random sampling of subjects, this study provides valuable information on the influence of smoking on periodontal status of Thai people.

In conclusion, the present study revealed a marked association between cigarette smoking and the risk of periodontitis among a group of older Thai adults. The odds of having severe periodontitis increased considerably among current smokers and showed a dose-dependent relationship with the amount of cigarette consumption. For former smokers, the fewer cigarettes smoked and longer duration since quitting smoking were associated with a lower risk for severe periodontitis.

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