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Periodontal attachment loss attributable to cigarette smoking in an urban Brazilian population

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Abstract

Aims: The present study estimated the percentages of cases with severe periodontal attachment loss (PAL) attributable to cigarette smoking in a representative adult urban population in southern Brazil.

Methods: A representative sample comprising 853 dentate individuals (age: 30–103 years) was selected by a multistage, probability sampling method. A full-mouth clinical examination of six sites per tooth was performed and an interview using a structured written questionnaire was undertaken. Cases were defined as individuals with $\geqslant$30% teeth with PAL $\geqslant$5 mm. A multivariate logistic regression analysis for complex surveys was performed, and adjusted for age, gender, race, socioeconomic status and dental calculus.

Results: The prevalence of cases in this population was 49.7%, or 739,000 subjects. Overall, 50.9% of this adult population, or approximately 757,000 subjects have had a lifetime exposure to cigarette smoking. Multivariate analysis showed that heavy and moderate smokers had a significantly higher risk for PAL $\geqslant$5 mm than non-smokers (odds ratio = 3.6, 2.0, respectively) after adjusting for the above covariates. We estimated that the number of moderate and heavy smokers with $\geqslant$30% teeth with PAL $\geqslant$5 mm might be reduced by approximately 28% and 48%, respectively, had they not smoked cigarettes. We project that a smoking cessation program could result in a reduction in the number of cases by up to 12% in this population, or approximately 90,000 potential cases.

Conclusion: Cigarette smoking was strongly associated with severe attachment loss in this population. A significant percentage of cases may have been prevented if smoking cessation interventions had been implemented. The results support the implementation of population-based smoking cessation programs to reduce the prevalence of severe attachment loss in populations with high level of smoking exposure.

Key words: attributable fraction; attributable risk; periodontal attachment loss; periodontal disease/epidemiology; risk factors; smoking

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Smoking has been recognized as one of the major risk factors for a number of diseases in humans, and implicated in a substantial proportion of the global burden of these diseases (Ezzati et al. 2002). Smoking has also been associated with periodontal disease pathogenesis (Gelskey 1999, Albandar 2002) and a significant increase in risk for periodontitis (Albandar et al. 2000, Tomar & Asma 2000, Hyman & Reid 2003).

Despite the wide popularity of using estimates of relative risk and odds ratio (OR) as the basis for assessing the association between smoking and periodontal diseases, neither of these two methods take into consideration the prevalence of the exposures in the population (Walter 1976, Benichou 2001). In addition, the OR may not be a good estimate of relative risk when disease outcome is high. An exposure that highly increases the person's risk for a certain disease or condition may be of limited public health importance if only a small percentage of cases are attributed to this exposure. Hence, a better appreciation of the population impact of a given exposure should also incorporate an inference of the number of cases that may be attributed to the exposure (Walter 1976, Ezzati et al. 2002).

The concept of population attributable fraction (PAF) was introduced in the

1950s to estimate how much of the disease burden could be attributed to a given risk factor, or may be prevented by its elimination or reduction. Various terms have been used to refer to the frequency of cases attributable to a given exposure, including the terms attributable risk, etiologic fraction and excess fraction (Kleinbaum et al. 1982, Rockhill et al. 1998a). Some of these terms have been criticized for their implicit causality, and it has therefore been suggested that the term attributable fraction may be preferable (Rockhill et al. 1998a).

Few studies have attempted to estimate the fraction of destructive periodontal diseases that could be attributed to smoking in different populations. Analysis of the NHANES III data suggests that a significant proportion of attachment loss in the American population may be attributed to cigarette smoking (Tomar & Asma 2000, Hyman & Reid 2003). However, little data are available from other populations. The aim of the present study was to estimate the number and percentage of cases with severe attachment loss attributable to cigarette smoking in a representative adult urban population in southern Brazil.

Table 1. Sociodemographic and other characteristics of dentate individuals in the study population

Variables	Dentate sample, *N*	Dentate population		Individuals with PAL ⩾5 mm in ⩾30% of the teeth	
		%	*N* (thousands)	%	SE
Age (years)					
30–39	294	40.4	601	22.3	1.7
40–49	253	30.4	451	57.5	3.6
50–59	175	16.6	247	65.4	3.0
60–69	84	8.6	127	73.0	4.1
70+	42	4.1	60	91.7	3.7
Gender					
male	385	47.4	705	54.9	3.7
female	463	52.6	782	40.5	1.4
Race					
White	681	80.3	1,195	46.2	1.4
non-White	167	19.7	292	51.7	4.0
Socioeconomic status					
low	342	43.0	639	54.4	2.5
medium	235	26.5	394	46.1	4.4
high	271	30.5	453	38.4	2.0
Smoking					
non-smokers	419	49.1	731	37.6	1.5
light	147	17.9	266	39.6	3.8
moderate	139	17.1	254	55.5	3.7
heavy	143	15.9	237	76.1	3.8
Supragingival calculus (%)					
<25	347	41.6	619	23.8	2.5
25–50	254	30.0	446	49.1	2.2
>50	247	28.4	423	79.9	1.9

Total dentate adults population = 1,487,025 subjects.
PAL, periodontal attachment loss; SE, standard error.

Material and Methods

Population

The target population of the present study was adults aged 30 years and older living in the metropolitan area of Porto Alegre in the Brazilian state of Rio Grande do Sul. This state is located in the southern part of Brazil, neighboring Argentina and Uruguay. The present survey covered 14 major municipalities from the Porto Alegre metropolitan area with about 3 million inhabitants.

Study design

The study sample included 974 individuals with an age range of 30–103 years, and comprised 388 (45.5%) males and 465 (54.5%) females, 686 (80.4%) whites and 167 (19.6%) non-whites. Table 1 shows the distribution of subjects by demographic and other important variables in the sample and the target population. The study group comprised 853 dentate and 121 edentulous subjects. Data for five subjects were not complete for some variables, and were excluded from the analysis.

The study sample was drawn from a larger sample representative of subjects aged 14 years and older among the population of Porto Alegre. A representative, multistage, probability sample was derived based on information provided by Rio Grande do Sul state government agency for metropolitan affairs (METROPLAN) and the Brazilian Institute of Geography and Statistics (IBGE). Using area maps, the Porto Alegre metropolitan area was divided into 90 geographic areas 10 km^2 each. Using the 1991 census data (IBGE 1991) and other relevant municipal information (METROPLAN 1997) these geographic areas were stratified into 13 (14.4%) high-income, and 77 (85.6%) low-income status areas. Low-income geographic areas were defined as areas in which more than 40% of the head of the households had a monthly income ⩽2 standard Brazilian salaries (about US$ 180), and high-income areas were those with a higher level of income. Within each of these two income strata, primary sampling units (PSUs) were selected randomly with a probability proportional to size and using a sampling frame of these PSUs. A total of 11 geographic areas were selected, and included two (18.2%) areas with high, and nine (81.8%) areas with low-income status.

The second stage consisted of selecting area sectors within each geographic area. The area sectors have been defined by IBGE as map areas comprising approximately 300 households each. The sectors were selected randomly within each geographic area, and the number of sectors selected was proportional to the number of sectors in each area. Thirty (3.5%) sectors were selected, out of a total of 846 eligible sectors. Approvals for conducting the study were sought separately in each sector from key community, religious and/or administrative leaders. Permission and/or support were granted to access 29 of these sectors, whereas permission to access one sector was denied.

The third stage included selecting households within each of the 29 sectors. It was estimated that approximately 25 households were needed per sector to provide a sufficient number of subjects in the sample. In each sector, a starting point for the selection of households was established on area maps and was provided independently by the IBGE. Households were sampled consecutively beginning with the next block after the starting point and until the preset number of households was reached.

Consenting household members who were 14 years of age or older were examined, and subjects 30 years or older were included in this study. Exclusion criteria were presence of diseases/conditions that may pose health risks to the participant or examiner, or that may interfere with the clinical examination. Hence, subjects were excluded if they were diagnosed with psychiatric problems, or intoxicated with alcohol or drugs. Individuals requiring a prophylactic regimen of antibiotics were provided with the appropriate medicine before the clinical examination.

Interviews and clinical examination

Three interviewers performed the interviews using a structured written questionnaire. The interviewers were trained before the study, and used standardized procedures to increase consistency. The clinical examinations were performed in a mobile examination unit consisting of a trailer equipped with a complete dental unit, comprising a dental chair, light, compressor and other basic amenities. The examination unit was moved from one examination location to the next according to the survey schedule. Four dentists and two dental assistants completed the fieldwork between June and December 2001. Letters were sent to households and explained the aims of the study and solicited participation. A few days later, one dentist visited the households and provided more information about the study and encouraged participation. Eligible subjects who consented to participation were interviewed to gather demographic, socioeconomic, oral health and other health-related data.

Trained dental assistants recorded the data on prepared record sheets. All permanent fully erupted teeth, excluding third molars, were examined with a manual periodontal probe (PCP10-SE, Hu-Friedy Mfg. Co. Inc., Chicago, IL, USA) color coded at 1, 2, 3, 5, 7, 8, 9, 10 mm. Six sites per tooth were assessed in the mesiobuccal, midbuccal, distobuccal, distolingual, midlingual and mesiolingual sites.

Probing depth was defined as the distance from the free gingival margin to the bottom of the pocket/sulcus. Gingival recession was defined as the distance from the cemento-enamel junction (CEJ) to the free gingival margin, and this assessment was assigned a negative sign if the gingival margin was located coronal to the CEJ. Periodontal attachment loss (PAL) was defined as the distance from the CEJ to the bottom of the pocket/sulcus, and was calculated as the sum of the probing depth and gingival recession measurements. Measurements were made in millimeters and were rounded to the lower whole millimeter.

Ethical considerations

The study protocol was reviewed and approved by the following committees: Research Ethics Committee, Federal University of Rio Grande do Sul, Porto Alegre, Brazil; the National Commission on Ethics in Research, Ministry of Health, Brasilia, Brazil and Ethics in Medical Research Committee, University of Bergen, Bergen, Norway. Subjects who agreed to participate signed an informed consent form. At the conclusion of the study the participants were provided with a written report detailing their oral status and any diagnosed mucosal lesions. Patients with diagnosed pathological conditions were advised to seek specialist consultation and treatment.

Non-response analysis

In the whole population, including individuals aged 14 years and older, 2435 individuals were eligible for the survey. Of these, 1586 (65.1%) subjects were clinically examined. Among those who did not participate, 127 (5.2%) refused to participate, 26 (1.1%) were unable to attend the examination site because of a physical disability, 60 (2.5%) were interviewed but refused to be examined and 636 (26.1%) were not at home. Subsequent to the completion of the examinations, a random sample of 339 (39.9%) subjects was selected out of 849 eligible subjects who either refused to participate or were not available during the normal survey schedule. Attempts were made to contact the selected subjects by telephone in order to collect data for the non-response analysis. Of the 339 subjects selected for interview, 50 (14.7%) subjects and their households were not available on two telephone call attempts, and an additional 18 (5.3%) subjects refused to be interviewed.

Non-response data were obtained for 271 (79.9%) subjects, and these will be referred to in the text as the non-respondents. Of these, 127 subjects were present and agreed to the telephone interview. The other 144 subjects were not available on two telephone call attempts, and the non-response data were therefore obtained through a first-degree relative living in the same household. The information collected included the subject's gender, age, education, dental care visits and income level. In addition, information about the number of teeth present was collected for the 127 subjects who were present during the telephone interview.

The mean age of the non-respondents group was 35.2 years, and included 51.3% males and 48.7% females, and 90.8% whites and 9.2% non-whites. In contrast, the mean age of the study group was 38 years, and included 45.3% males and 54.7% females, and 82.5% whites and 17.5% non-whites. By the number of years of education, the non-respondents and respondents groups, respectively, included 7.4% and 22.3% subjects with 4 or fewer years, 22.5% and 40.0% subjects with 5–8 years, and 70.1% and 37.8% subjects with more than 8 years of education. This suggests that the non-respondents were similar to the study group in the mean age, but included somewhat higher percentages of males and whites, and had a higher number of years of education than the study participants. A weight variable was used in the data analysis to minimize the bias in the population parameter estimation (Korn & Graubard 1999), which may arise because of the sample non-response. The calculation of the weight variable was based on census information provided by IBGE (IBGE 1996).

Measurement reproducibility

The examiners were trained and calibrated in performing the clinical measurements before and during the field examinations. The examination team followed a quality control protocol that was aimed at reducing systematic and random measurement errors and to quantify what error remained. The protocol involved standard examination environment and methodology, standard equipment and detailed written instructions for clinical procedures.

Assessment of measurement reproducibility used replicate periodontal measurements performed during the fieldwork. One examiner with the most clinical experience served as the ''gold standard'' examiner. A total of 57 subjects, divided into four groups ranging from eight to 20 subjects, were used for the reproducibility assessment. In one of the groups, the replicate measurements consisted of repeated measurements by the gold standard examiner. In each of the remaining three groups, the replicate measurements were made by one examiner and the gold standard examiner. Measurement reproducibility at the subject level was assessed by the intraclass correlation coefficient (Shrout & Fleiss 1979) and weighted κ, and at the site level by the weighted κ (Hubert 1977). The intraclass correlation coefficients for mean PAL ranged between 0.95 and 0.99, and for extent scores of PAL $\geqslant 5$ and $\geqslant 7$ mm ranged between 0.80 and 0.98. The weighted κ's ($\pm$ 1 mm) of the prevalence of PAL $\geqslant 5$ mm were between 0.69 and 1.00, and at site level ranged between 0.65 and 0.87. The intraclass correlation coefficients for supragingival calculus ranged between 0.73 and 0.98 at the site level, and between 0.66 and 0.99 at the tooth level.

In order to assess the reliability of the self-reported smoking variable, 79 subjects of the study sample were re-interviewed a second time by the gold standard examiner. The second interview was made 1–4 days after the first. The unweighted κ for smoking (categorized as non-smokers, light, moderate and heavy smokers) was 0.92.

Data analysis

The mean tooth loss in this dentate population was 9.2 teeth. At a given tooth, attachment loss was scored as the maximum of attachment loss measurements at six sites per tooth. The outcome variable was presence of severe attachment loss, defined as subjects with PAL $\geqslant 5$ mm in $\geqslant 30\%$ of the teeth. Exposure to cigarette smoking was calculated for current and former smokers. Number of cigarettes consumed per day was multiplied by the number of days of habit, and divided by 20 (one pack) to calculate the total number of packs of cigarettes consumed in a lifetime. Smokers were classified using smoking thresholds selected according to tertiles among current and former smokers into heavy (>7300 packs), moderate (2735–7300 packs), light (1–2734 packs) and non-smokers (<1 pack). The four smoking categories are comparable with a consumption of >20 pack years (or = 1 pack/day for >20 years), 7.5–20 pack years (or $\sim$ 1 pack/day for 7.5–20 years), 0.1–7.4 pack years (or $\sim$1 pack/day for 0.1–7.4 years) and <0.1 pack years, respectively. The classification by smoking status did not differentiate between current and former smokers.

The race of the subject was scored as ''White'' or ''non-White'', with blacks, mulattos and other ethnic groups scored as ''non-Whites''. Socioeconomic status was scored by combining information about family economy using a standard Brazilian economy classification (CCEB) and the level of education of the individual. High socioeconomic status was defined as having 9 years of education and being in the upper two tertiles of the CCEB economy classification, or having 5–8 years of education and being in the highest tertile of the CCEB classification. Low socioeconomic status was defined as having 1–4 years of education, and being in the lowest two tertiles of the CCEB classification, or having 5–8 years of education and being in the lowest tertile of the CCEB classification. Individuals who had higher economy and education than the low socioeconomy group, but less than the high group were classified as having a medium socioeconomic status. Based on tertiles of the percentage of sites with supragingival dental calculus the subjects were grouped into three groups: $<25\%$, 25–50% and $>50\%$ sites.

Attributable fraction among exposed subjects (AF_{exp}) estimates the absolute excess risk for an outcome variable associated with a given exposure, i.e. the fraction of exposed cases that would not have occurred if exposure had not occurred (Kleinbaum et al. 1982, Rockhill et al. 1998a, Szklo & Nieto 2000). In this study, attributable fraction among smokers estimates the absolute excess risk for severe attachment loss because of smoking, or the fraction of smokers who would not have severe attachment loss if smoking had not occurred. Percent attributable fraction among exposed ($\%AF_{exp}$) simply converts the attributable fraction among exposed into the percentage of smokers with severe attachment loss because of smoking. PAF is the proportion of reduction of attachment loss risk that could be achieved by eliminating smoking from the population while other risk factors remain unchanged. Percentage population attributable fraction (%PAF) converts the PAF into percentage of subjects with severe attachment loss which is preventable, in the entire population. The following formulas (Szklo & Nieto 2000) were used:

- $AF_{exp} = p_1 – p_2$,
- $\%AF_{exp} = \frac{(p_1 - p_2)}{p_1} \times 100$,
- $PAF = p_0 – p_2$,
- $\%PAF = \frac{(p_0 - p_2)}{p_0} \times 100$,

where p_0 is the probability of having severe attachment loss among all subjects; p_1 is the probability of having severe attachment loss among smokers in each smoking category; p_2 is the probability of having severe attachment loss among non-smokers.

The present analysis took into account the design of the survey, including stratification, clustering and weighting. A logistic model for complex survey was used to predict the probability of the outcome, expected prevalence and number of cases. The estimates were adjusted for age, socioeconomic status, gender, race and presence of supragingival calculus. After the initial model was calculated, the exposure effect, i.e. smoking, was removed from the dataset by resetting the covariate to zero, and the probability of the outcome in the logistic model was predicted again. The resulting estimates are the predicted probability of the outcome if the exposure had been removed. Summing these probabilities gives the expected prevalence and number of cases of disease if the exposure was absent or removed from the population (Greenland & Drescher 1993, Benichou 2001).

Results

Overall, 50.9% of this adult population, or approximately 757,000 individuals have been exposed to cigarette smoking

Table 2. Estimated ORs (crude and adjusted) with 95% CI and the attributable fractions (%AF_{exp} and %PAF) because of smoking on the occurrence of attachment loss[‡]

	Crude OR	95% CI	Adjusted OR[†]	95% CI	%AF_{exp}	%PAF
non-smoker	1.0		1.0			
light	1.1	0.7–1.7	1.2	0.7–2.2	0.6	1.2
moderate	2.1**	1.4–3.1	2.0**	1.4–2.9	27.7	4.2
heavy	5.6**	3.5–9.0	3.6**	2.2–6.0	48.1	6.8
overall						12.2

%AF_{exp}, percentage attributable fraction among exposed; %PAF, percentage population attributable fraction; OR, odds ratio; CI, confidence interval.

*Defined as periodontal attachment loss ⩾5 mm in ⩾30% of the teeth.

‡Adjusted for age, gender, race, socioeconomic status, and supragingival calculus.

**$p < 0.01$.

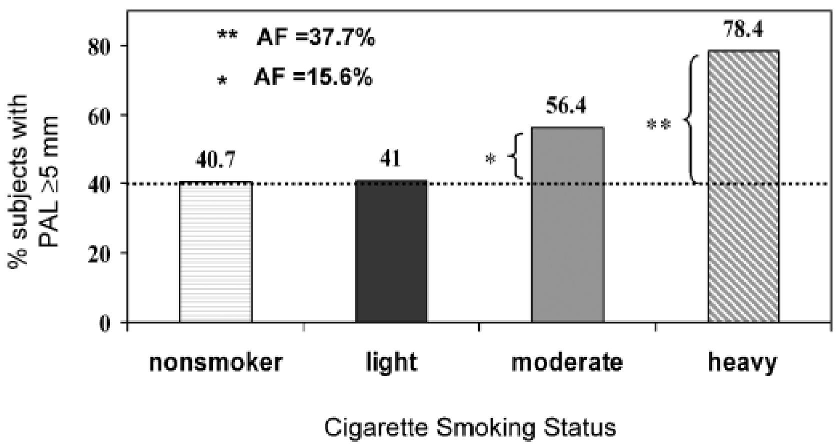

Fig. 1. Percentage of subjects with attachment loss ⩾5 mm at ⩾30% of the teeth, adjusted for age, gender, race, socioeconomy, and dental calculus; and the attributable fraction because of smoking (attributable fraction, AF), by smoking status.

(Table 1), and 49.7%, or 739,000 subjects had PAL ⩾5 mm at ⩾30% of the teeth. PAL ⩾5 mm was significantly more prevalent among heavy ($p = 0.0001$) and moderate ($p = 0.002$) smokers than among non-smokers (Table 1), and was not significantly different in light smokers compared with non-smokers ($p > 0.05$).

Univariate analysis showed that heavy (OR = 5.6) and moderate smokers (OR = 2.1) had higher probability of having severe attachment loss than non-smokers. Multivariate analysis showed that heavy and moderate smokers had higher risk for severe attachment loss than non-smokers (OR = 3.6, 2.0, respectively) after adjusting for age, gender, race, socioeconomic status and dental calculus (Table 2).

The percentage of subjects with severe attachment loss, adjusted for the covariates, was positively correlated with smoking status (Fig. 1). The attributable fraction of attachment loss because of cigarette smoking was 37.7% and 15.6% among heavy and moderate smokers, respectively, and only 0.3% among light smokers. Approximately 28% and 48% of the cases of severe attachment loss could be prevented among moderate and heavy smokers, respectively (Table 2).

In the whole population, 6.1%, or 90,400 individuals had PAL ⩾5 mm at ⩾30% of the teeth, attributable to cigarette smoking (Fig. 2). Light smoking contributed only 0.6% to the overall occurrence of PAL ⩾5 mm in ⩾30% of the teeth, whereas moderate and heavy smoking, respectively, had 2.1% and 3.3% attributable fraction in the population. We project approximately a 12% decrease in the percentage of subjects having ⩾30% teeth with PAL ⩾5 mm if cigarette smoking was completely eliminated in this population, and a larger number of cases may be prevented among heavy smokers than moderate or light smokers (Table 2).

The percentage of subjects with severe attachment loss attributable to smoking in the population was similar in the 30–39 and 40–49 years old groups, and considerably lower in the 50+ years old group (Table 3). The percentage of PAL attributable to smoking among heavy smokers was considerably higher among individuals 30–39 years old compared with individuals 50+ years old (71.0% versus 27.7%).

Discussion

Half of the subjects in this urban adult Brazilian population have been exposed to cigarette smoking. In addition, half of the population had ⩾30% of their teeth showing PAL ⩾5 mm. We estimate that the number of moderate and heavy smokers with ⩾30% teeth with PAL ⩾5 mm may be reduced by approximately 28% and 48%, respectively, if these individuals had not been smokers. We also project that a smoking cessation program could result in a reduction in the percentage of cases by up to 12% in this population, or approximately 90,000 potential cases. Clearly, the projected number of preventable cases will depend on the success of the smoking cessation program.

Two recent studies (Tomar & Asma 2000, Hyman & Reid 2003) used data from the NHANES III survey and estimated a higher potential reduction in the percentage of attachment loss cases in the US population than was found in this study. Tomar & Asma (2000) defined cases as subjects with one or more periodontal sites that had a probing depth as well as PAL ⩾4 mm, and estimated that 41.9% and 10.9% of the cases were attributable to current and former smoking, respectively. Among current smokers, 74.8% of the cases could be attributed to smoking, while among former smokers the percentage of cases was 40.5%. On the other hand, Hyman & Reid (2003) defined cases as the 10% of the population with the greatest mean attachment loss within each age group, and estimated that the smoking attributable fraction for US current smokers was 82% and 84% cases in the 20–49 years and 50+ years old groups, respectively. They also estimated that the attributable fractions for the whole US population (smokers and non-smokers) were 60% and 47% cases in the two respective age groups. The differences in the estimates of PAF between the two studies appear to be related to the definition of cases,

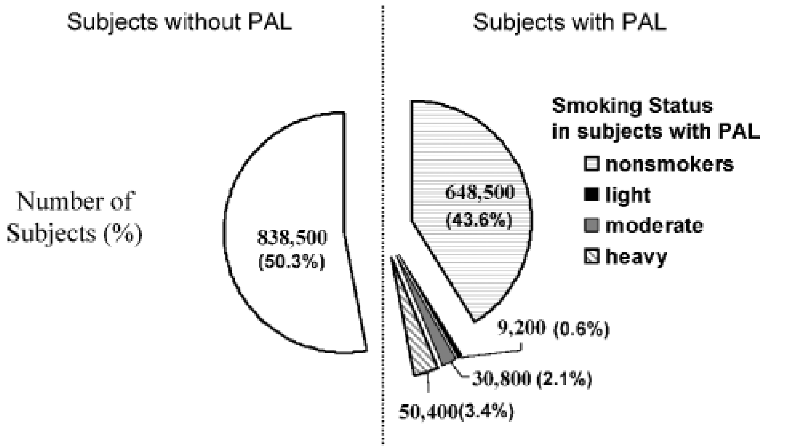

Fig. 2. Population attributable risk (%) because of smoking, and the number of subjects with attachment loss $\geqslant 5$ mm at $\geqslant 30\%$ of the teeth, by smoking status.

Table 3. Estimated odds ratios (crude and adjusted) with 95% CI and the attributable fractions (%AF_{exp} and %PAF) due to smoking on the occurrence of attachment loss‡, by age group

	Crude OR	95% CI	Adjusted OR†	95% CI	%AF_{exp}	%PAF
30–39 years old						
non-smoker	1.0		1.0			
light	1.4	0.4–4.3	1.0	0.3–3.0	21.8	− 0.3
moderate	2.4	1.0–6.3	1.5	0.4–5.3	50.2	5.3
heavy	6.1**	2.0–18.7	2.4*	1.1–5.4	71.0	8.3
overall						13.3
40–49 years old						
non-smoker	1.0		1.0			
light	1.5	0.8–2.7	1.3	0.7–2.3	18.5	1.5
moderate	3.5**	2.1–5.8	2.5*	1.1–5.7	41.5	5.8
heavy	6.9**	3.3–14.4	4.2*	1.4–12.6	51.7	8.9
overall						16.2
50+ years old						
non-smoker	1.0		1.0			
light	1.0	0.4–2.3	1.2	0.5–3.2	− 2.2	0.8
moderate	2.2	0.6–7.3	2.0	0.7–5.5	18.4	1.8
heavy	4.6**	2.5–8.5	2.5**	1.4–4.5	27.7	2.7
overall						5.3

%AF_{exp}, percentage attributable fraction among exposed; %PAF, percentage population attributable fraction; OR, odds ratio; CI, confidence interval.
‡Defined as periodontal attachment loss $\geqslant 5$ mm in $\geqslant 30\%$ of the teeth.
†Adjusted for age, gender, race, socioeconomic status, and supragingival calculus.
*$p < 0.05$,
**$p < 0.01$.

as well as the thresholds of smoking exposures used in the two studies. A recent study used a case–control design and adjusted for important risk indicators of periodontal disease, and it estimated that 12% of chronic periodontitis cases could be attributed to smoking (Teng et al. 2003), which is similar to the finding of this study.

For a given exposure, the magnitude of the PAF in the population is directly related to the degree of association between the exposure and the outcome (measured by one of three methods: the probability of having the disease, relative risk or OR), and the prevalence of exposure (Benichou 2001). The percentage of Brazilians who had smoked in the present population was 50.9%. Similarly, it has been estimated that 51.1% of the American population had been exposed to cigarette smoking (Tomar & Asma 2000). On the other hand, the overall association between smoking and periodontal disease was somewhat weaker in this study population (OR = 1.9) than was reported in the American population (OR = 2.7). The latter difference may explain part of the disparity in the estimated smoking attributable fraction in the two populations.

In multifactorial diseases the contribution of all plausible and potential risk factors should be investigated, since the estimated value of PAF may be influenced by the study design, including the types of covariates used in the model. The estimated PAF measures the reduction in PAL which could be achieved, given that all other factors remain unchanged (Greenland & Drescher 1993, Rockhill et al. 1998a, Benichou 2001).

The multivariate approach used in the present study included covariates with variable degrees of associations with periodontal diseases. Our analytical model adjusted for the effect of supragingival calculus, as a measure of oral hygiene, when assessing the association between smoking and PAL. In contrast, previous studies did not adjust for this variable. Notably, in the present analysis, excluding the calculus variable from the analytical model resulted in an increase in the estimate of %PAF from 12.2% to 19.8%. Hence, it is likely that the higher estimates of %PAF reported by other studies may also be attributed to the lack of adjustment for dental calculus.

In the present analysis, we predicted the number of exposed individuals (smokers) with or without severe attachment loss, and these estimates were used in the calculation of the PAF estimates (Greenland & Drescher 1993, Benichou 2001). In contrast, Hyman & Reid (2003) and Tomar & Asma (2000) used the prevalence of smoking in their populations and the respective OR for smoking, in the calculation of PAF estimates. The latter method is based on the assumption that the OR is an approximation of the relative risk when the prevalence of disease is low (<10%) (Zhang & Yu 1998, Szklo & Nieto 2000, Eide & Heuch 2001). However, this Brazilian population had a relatively high prevalence of severe attachment loss, and the assumption used in previous studies may, therefore, not be valid. The difference in the analytical approach between this and the two other studies may also have contributed to some of the difference in the PAF estimates between these studies.

It has been suggested that analytical models which involve attributable fraction estimation should include only variables that are causally associated with the disease and that are modifiable through prevention and intervention (Rockhill et al. 1998a, b, Szklo & Nieto 2000, Eide & Heuch 2001). Surveys may provide valuable data about the occurrence of disease and prevalence of potential risk factors in populations, but they do not provide proof of causality (Albandar & Rams 2002). Moreover, this study design may provide important information needed to calculate PAF values, not feasible with other study designs (Walter 1976).

For smoking, current knowledge suggests that there is a strong association between this variable and destructive periodontal diseases, and enough evidence does exist to characterize smoking as a true risk factor of these diseases (Gelskey 1999, Albandar 2002). In this regard, our findings are consistent with other studies showing a significant effect of cigarette smoking on the occurrence of periodontal diseases (Grossi et al. 1994, Gelskey 1999, Albandar et al. 2000, Bergstrom et al. 2000, Corbet et al. 2001, Hyman & Reid 2003).

Most studies that have addressed the relationship between smoking and periodontitis have been based on a self-reported assessment of tobacco consumption. Self-reporting may be influenced by cultural and social factors, and the effects of smoking on health may also be influenced by individual variations because of differences in metabolism, depth of inhalation, and nicotine concentration in cigarettes. An alternative approach to self-reporting may include the assessment of specific metabolites, such as cotinine, which are present in serum following tobacco consumption. The assessment of metabolites, however, may measure smoking levels in current smokers only (Scott et al. 2001, Spiekerman et al. 2003). Furthermore, the self-reported assessments showed a very high level of reproducibility in this study population ($\kappa = 0.92$).

While interesting from a conceptual point of view, the complete elimination of an exposure is often an unattainable public health goal, whereas a reduction in the prevalence and severity of exposure is a more realistic objective (Rockhill et al. 1998a, b). Hence, a decline in the smoking PAF and the overall prevalence of severe attachment loss in the population may be expected if preventive interventions were applied. Moreover, since exposure to a risk factor is cumulative in nature, cessation of exposure should not reduce the risk in previously exposed individuals to the same level observed in those that have never been exposed (Szklo & Nieto 2000). Evidently, prevention of periodontitis in former smokers cannot be achieved by means of a smoking cessation program. Nevertheless, inclusion of former smokers in the analysis is useful in the calculation of the total burden of disease that may be attributed to smoking.

A multidisciplinary approach is probably the most appropriate strategy for the prevention of periodontal diseases. Consequently, targeting exposures that also are risk factors for systemic diseases may have a better chance of success, and may also enhance the benefits and effectiveness of public health interventions (Ezzati et al. 2002). Since smoking is also an important risk factor for other diseases, a common risk factor approach would be to include periodontal diseases in ongoing or planned intervention campaigns designed to prevent smoking-related diseases (Sheiham & Watt 2000).

Cigarette smoking was strongly associated with severe attachment loss in this study population, and a significant percentage of cases might have been prevented if smoking cessation interventions had been implemented. The results suggest a need for population-based smoking cessation programs in an attempt to reduce the incidence of severe attachment loss in populations with high level of smoking exposure.

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