Periodontitis and Smoking: An Evidence-Based Appraisal

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INTRODUCTION

The awareness of the harmful effects of tobacco smoking on many organs and tissues in the body has gradually increased in the general population and bans on smoking in public places are becoming more and more common in many countries. In dentistry the harmfulness of smoking, surprisingly, has gained only limited concern. In spite of the fact that there is substantial knowledge to verify the effects of smoking on oral tissues, dental care in general has devoted very little time and effort to the information about these untoward effects. One reason for this negligence may be that the effects of smoking on oral and, in particular, periodontal health are insufficiently appreciated or underestimated.

Although the first reports on smoking and its potential effects on periodontal health emanate from the early 1950s, a more thorough understanding or acceptance of smoking as a periodontal health risk began with the appearance of 3 independent publications in 1983.[1-3] Since then, a gradually increasing interest in the relationship between smoking and the periodontal health condition has emerged. Over the past 10 to 15 years smoking has gained scientific acceptance as an important risk factor for destructive periodontal disease. In addition, the potential interference of smoking with the outcome of various periodontal therapies has been addressed in a number of investigations. The objective of the present systematic review, therefore, is to give a critical appraisal of the available literature on the subject to establish an evidence base regarding (1) the relationship between smoking and the periodontal health condition and (2) the influence of smoking on periodontal therapy outcome.

METHOD

A search in medical databases using MeSH terms related to "smoking" and "periodontal…" resulted in approximately 1050 hits. A further selection including clinical and epidemiological studies in humans alone resulted in a retrieval of 577 titles. A narrowing to include studies that only used measures of the periodontal destruction such as pocket probing depth, attachment level (or attachment loss), bone height (or bone loss), and tooth frequency further reduced the number of titles. Thus, studies that have used descriptors of inflammatory change alone such as gingival bleeding or gingival index were excluded. In addition, reviews, nonoriginal research articles, and opinionated statements have been excluded. In the final analysis, 129 titles including 105 titles referring to population observational studies and 24 titles referring to periodontal therapy intervention studies have been evaluated.

RESULTS

Population Studies

Overall, the population studies that have addressed the relationship between smoking and periodontitis include 70 cross-sectional,[1-70] 14 case-control,[71-85] and 21 cohort[86-107] studies. The measures of the periodontal condition that are used as effect measures or endpoints in the population studies are periodontal pocket depth (PPD), clinical attachment level (or loss, CAL), periodontal bone level (or loss, PBL), and number of retained (or lost) teeth. Frequently more than one of these endpoints are used. A majority of population studies is based on 200 or more individuals.

1. Cross-sectional studies The most common type of population study is the cross-sectional study. Almost 70% of the population studies belong to this category representing 19 different nations The number of participants in the cross-sectional studies varies from 82 to 12,329, with an average of 1692 individuals per study. More than 80% of cross-sectional studies are based on 200 or more individuals (Table 1). Altogether, the cross-sectional studies cover a total of 79,444 individuals. Most cross-sectional studies concern a broad age range, and approximately 90% of the studies cover the ages 20 to 70 years or 40 years and above (Table 2). In 56% of the cross-sectional studies endpoint is used and in 34% 2 endpoints are used (Table 3). The most frequently applied endpoints are PPD, used in 53% of studies, and CAL, used in 50% of studies (Table 4).

Irrespective of endpoint, all cross-sectional studies demonstrate a statistically significant association between smoking and an impaired periodontal health condition suggesting that on the average smokers exhibit greater periodontal morbidity than nonsmokers. Statistical significance testing is presented in all studies, and *P* values range from less than .001 to less than .05. A summary of the results appears in Table 5. In 97% of 37 studies using PPD as the only or one of several endpoints, a significant association with smoking is demonstrated. Similarly, all 35 studies that use CAL, all 16 studies that use PBL, and 95% of 19 studies that use number of teeth

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Table 1. Distribution of population studies by study type and sample size

Sample Size	Study Type							
	Cross		Case-Control		Cohort		Total	
	n	%	*n*	%	*n*	%	*n*	%
< 200	11	16	8	57	7	33	26	25
200–1000	34	48	4	29	14	67	52	49
>1000	25	36	2	14	0	0	27	26
Total	70	100	14	100	21	100	105	100

Table 2. Distribution of population studies by study type and age interval covered in sample

Age Interval, y	Study Type							
	Cross		Case-Control		Cohort		Total	
	n	%	*n*	%	*n*	%	*n*	%
20–100	46	68	10	72	13	65	69	68
40–100	14	20	2	14	6	30	22	21
<40	8	12	2	14	1	5	11	11
Total	68	100	14	100	20	100	102	100

Table 3. Distribution of population studies by study type and number of endpoints

Number of Endpoints	Study Type							
	Cross		Case-Control		Cohort		Total	
	n	%	*n*	%	*n*	%	*n*	%
1	39	56	5	36	15	71	59	56
2	24	34	7	50	4	19	35	33
>2	7	10	2	14	2	10	11	11
Total	70	100	14	100	21	100	105	100

Table 4. Distribution of population studies by study type and endpoint

Endpoint	Study Type							
	Cross		Case-Control		Cohort		Total	
	n	%	*n*	%	*n*	%	*n*	%
PPD	37	53	8	57	5	24	50	48
CAL	35	50	4	29	8	38	47	45
PBL	16	23	6	43	11	52	33	31
TEETH	19	27	3	21	5	24	27	26

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

Table 5. Smoking and periodontal health condition in population studies. Number (*N*) and percentage (%) of studies indicating association of smoking with impaired condition by study type and endpoint

	Study Type							
	Cross		Case-Control		Cohort		Total	
Endpoint	*n*	%	*n*	%	*n*	%	*n*	%
PPD	36	97	8	100	4	100	48	96
CAL	35	100	4	100	7	88	46	98
PBL	16	100	6	100	11	100	33	100
TEETH	18	95	3	100	4	80	25	93

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

as the only or one of several endpoints indicate the same. In the 24 cross-sectional studies where 2 endpoints concurrently are used 23 (96%) suggest an association with either endpoint. Details are found in Table 6.

2. Case-control studies A total of 14 case-control studies emanating from 8 nations are included in the present analysis. The study base of the case-control studies ranges from 42 to 2612 individuals with an average of 482 individuals per study. Most case-control studies are based on fewer than 200 participants (Table 1). Altogether, 6744 individuals are covered. The age range is usually broad (Table 2). Two or more endpoints are frequently used in case-control studies. The most common endpoint single or in combination with others is PPD, applied in approximately 57% of studies (Tables 3 and 4).

All case-control studies irrespective of endpoint suggest that smoking is more common among cases than among controls, or that, among cases, smokers display more severe signs or symptoms than nonsmokers (Table 5). Statistical significance levels as reported in the studies range from *P* is less than .001 to *P* is less than .05. In 6 case-control studies where 2 endpoints are concurrently used both endpoints agree on the association between smoking and an impaired periodontal health condition (Table 6).

3. Cohort studies The 21 cohort studies analyzed are based on population samples from 6 nations ranging in size from 59 to 980 participants. Altogether, the cohort studies include a total of 7321 individuals with an average of 349 individuals per study. The follow-up length of the cohort studies varies from 1 to 28 years, the average length being 9.8 years. The typical cohort study concerns 200 to 1000 participants of a broad age range and uses a single endpoint (Tables 1 to 3). The most frequently applied endpoint is PBL (Table 4).

It appears that 95% of the 21 cohort studies provide evidence of an association between smoking and disease onset or progression, thus suggesting that the deterioration of the periodontal health condition over time is greater in smokers than nonsmokers (Table 5). Significance testing is reported in all studies, presenting statistical probabilities ranging from *P* is less than .001 to *P* is less than .08. In 3 of the 4 cohort studies where 2 endpoints are concurrently used, the association is valid with either endpoint (Table 6).

One study deviates from the general trend and suggests no difference between smokers and nonsmokers.[106] This study concerns an Australian population including 342 individuals

Table 6. Association between smoking and periodontal health condition in population studies with 2 endpoints. Frequency of studies showing agreement or disagreement by study type and endpoint combination

	Study Type							
Endpoint	Cross		Case-Control		Cohort		Total	
Combination	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
PD+CAL	11	1	2	0	0	0	13	1
PD+PBL	6	0	2	0	1	0	9	0
PD+TEETH	2	0	0	0	0	0	2	0
CAL+PBL	1	0	1	0	1	0	3	0
CAL+TEETH	2	0	0	0	0	0	2	0
PBL+TEETH	1	0	1	0	1	1	3	1
Total	23	1	6	0	3	1	32	2

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

60 years of age and older at baseline and followed-up after 5 years using CAL as the endpoint. It is reported that losses to follow-up were considerable (almost 60%) in this study, which might explain the lack of agreement with the results of other studies.

COMMENTS AND EVIDENCE INTERPRETATION OF POPULATION STUDIES

More than 100 studies including about 90,000 individuals distributed among cross-sectional and case-control as well as cohort studies were included in the present appraisal. Altogether, the analysis shows an overwhelming consistency among study results indicating that the periodontal health condition of smokers is significantly inferior to that of nonsmokers. As the studies were based on data collected in populations from a great number of nations throughout the world—developed as well as developing—it seems justified to conclude that a harmful influence of smoking on periodontal health is applicable worldwide.

As expected, the cross-sectional study was the predominating study type, representing together with case-control studies 80% of all studies and over 90% of individuals examined. Although the evidence based on these 2 types of study may be considered weaker than that found from cohort studies, the consistent and unambiguous results obviously offer a stable basis for the argument that there is a strong association between smoking and periodontal health impairment. Cohort studies representing about 20% of the studies analyzed still constituted a sufficiently large number to contribute important information. As cohort studies are dynamic in the sense that changes over time can be detected and possibly linked to the factor under scrutiny they may reveal a cause-effect relation. The results of the cohort studies were consistent, the vast majority indicating that the periodontal health condition of smokers deteriorated over time in contrast to that of nonsmokers, or that the deterioration observed in smokers was greater than that in nonsmokers. Thus, the results of the cohort studies strengthen the reliability of the above argument based on static studies suggesting that smoking is the responsible or causal part of the association. One well-known problem with cohort studies is the sample attrition over time. This problem may be particularly cumbersome when studying smoking, a factor known to reduce life expectancy. This fact will inevitably lead to a greater reduction of smoker participation than of nonsmoker participation over time. This problem is certainly relevant to the cohort studies reviewed. Attrition rates, unfortunately, are seldom reported and, in particular, not for smokers and nonsmokers, separately. In addition, subjects who become edentulous over time are excluded in many studies. As a consequence, several cohort studies most likely underestimate the real effects of smoking.

Several measures are used as endpoints in the population studies, most commonly PPD and CAL, and, less frequently, PBL and tooth frequency. With the exception of the last one, these measures are based on anatomic features and commonly used as diagnostic signs in clinical periodontology. It may be argued whether or not measures of probing depth, attachment level, and bone level should be considered surrogate or true endpoints. They all, however, estimate the degree of periodontal destruction and, therefore, are measures of periodontal morbidity. Further, as these measures are normally found from a large number of single measurements in the individual, they must be considered to provide robust and reliable data. In many studies more than one of these measures were used as endpoints. As might be expected, since they are heavily correlated, concurrently applied endpoints most of the time agreed on the same result, which strengthens the overall consistency of the results.

On the basis of the present analysis that

- 100% of 70 cross-sectional studies and 100% of 14 case-control studies indicate an association between smoking and an impaired periodontal health condition, and
- 95% of 21 cohort studies indicate a greater periodontal health impairment rate in smokers than in nonsmokers,

it is concluded that there is strong evidence to suggest that smoking negatively interferes with a healthy periodontal condition. Thus, there is good evidence to recommend that smoking be specifically considered in a periodontal health examination (Recommendation grade A).

Intervention Studies

Publications regarding 2 types of periodontal therapy intervention study, nonsurgical therapy or the scaling and root planing procedure studies,[20,108-119] and surgical therapy studies,[91,108-110,120-129] sometimes including regenerative procedures such as guided tissue regeneration, are included in the present compilation. Both nonsurgical and surgical therapy intervention studies are based on comparably small sample sizes. The most common endpoints in these studies are PPD and CAL.

1. Nonsurgical therapy intervention studies The potential effect of smoking on the outcome of nonsurgical therapy intervention is addressed in 10 publications representing 4 nations. The studies include a minimum of 28 and a maximum of 398 cases with an average of 129 cases per study. Altogether, the nonsurgical therapy studies encompass a total of 1417 treated cases followed-up for an average length of 4.7 months. The mean age range of cases in the 8 studies that present age range data is 33.0 years with a mean minimum age of 31.1 years and a mean maximum age of 64.1 years. Two endpoints are used in 60% of the nonsurgical therapy intervention studies, the most frequently used endpoint being PPD (Tables 7 and 8).

Overall, 9 of the 10 nonsurgical therapy intervention studies (91%) report a significantly inferior outcome in smokers compared with nonsmokers. Outcomes by endpoint are presented in detail in Table 9. In 6 studies where 2 or

Table 7. Distribution of intervention studies by study category and endpoint applied

	Study Category					
	Nonsurgical		Surgical		Total	
Endpoint	*n*	%	*n*	%	*n*	%
PPD	10	91	8	57	18	72
CAL	5	45	4	28	9	36
PBL	0	0	4	28	4	17
TEETH	1	10	1	7	2	8

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

Table 8. Distribution of intervention studies by intervention category and number of endpoints

	Study Category					
	Nonsurgical		Surgical		Total	
Number of Endpoints	*n*	%	*n*	%	*n*	%
1	4	40	7	50	11	46
2	6	60	5	36	11	46
>2	0	0	2	14	2	8
Total	10	100	14	100	24	100

Table 9. Smoking and periodontal therapy outcomes in intervention studies. Number (*N*) and percentage (%) of studies indicating association between smoking and inferior therapy outcome by study category and endpoint

	Study Category					
	Nonsurgical		Surgical		Total	
Endpoint	*n*	%	*n*	%	*n*	%
PPD	9	90	5	62	14	78
CAL	4	80	8	100	7	88
PBL	0	0	4	100	4	100
TEETH	0	0	1	100	1	50

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

Table 10. Association between smoking and periodontal therapy outcomes in intervention studies with 2 endpoints. Frequency of studies showing agreement or disagreement on outcome by study category and endpoint combination

	Study Category					
	Nonsurgical		Surgical		Total	
Endpoint Combination	Agree	Disagree	Agree	Disagree	Agree	Disagree
PPD+CAL	4	1	3	1	7	2
PPD+PBL	0	0	0	1	0	1
PPD+TEETH	0	1	0	0	0	1
Total	4	2	3	2	7	4

PPD = periodontal pocket depth; CAL = clinical attachment level (loss); PBL = periodontal bone level (loss); TEETH = number of retained (or lost) teeth.

more endpoints are applied, there is agreement between any 2 endpoints in 4 instances (Table 10). Significance testing is reported in all studies and statistical probabilities as presented range from *P* is less than .001 to *P* is less than .05. The one study where the significance level is not met reports a trend toward an inferior outcome in smokers.[114]

2. Surgical therapy intervention studies Publications reporting on the potential effect of smoking on the outcome of periodontal surgical therapy intervention include 14 studies representing 8 nations. The studies cover a minimum of 14 and a maximum of 100 cases with an average of 45 cases per study. The mean age range in the 10 studies that present age range data is 38.6 years with a mean minimum age of 28.3 years and a mean maximum age of 66.9 years. The length of follow-up varies from 6 to 120 months. A majority of the studies reports a follow-up length between 6 and 12 months. In all, 629 cases have been followed-up for an average of 40.7 months. PPD is the most frequently used endpoint and 50% of the studies use one endpoint (Tables 7 and 8).

All surgical therapy intervention studies but one (93%) indicate an inferior outcome in smokers compared with nonsmokers. Details of study outcomes with regard to endpoint used are found in Table 9. Significance levels vary between *P* is less than .001 and *P* is less than .05. In 5 studies where 2 endpoints are used, outcomes agreement between any 2 endpoints is reported in 3 instances (Table 10). The one study that suggests no different outcomes in smokers and nonsmokers is a 10-year follow-up of 9 smokers and 11 nonsmokers. It is reported in the study that the outcome was inferior in the smokers although the difference was not statistically significant.

COMMENTS AND EVIDENCE INTERPRETATION OF INTERVENTION STUDIES

Overall, the results of the intervention studies suggest an inferior therapeutic outcome in smoker patients compared to nonsmoker patients. In 80% of studies the results were statistically significant. The rationale for nonsurgical therapy is to bring about resolution of inflammation by means of eliminating subgingival microbial deposits. When measured in terms of mean PPD reduction or mean CAL gain after a maximum of 9 months, the outcome *on the average* is less efficient in smokers than in nonsmokers. From a patient perspective, however, the important question is: "What is the risk for a nonsuccessful outcome?" None of the nonsurgical studies has evaluated the effect of smoking in terms of a successful versus a nonsuccessful outcome following predetermined criteria. Another important question is whether or not a negative short-term effect of smoking observed in terms of PPD or CAL holds true in the long run in terms of tooth loss, a more tangible outcome measure from a patient perspective. This is, unfortunately, still not known since all nonsurgical therapy intervention studies have too short a follow-up length for the determination of an effect on tooth loss. The long-term effects of smoking on nonsurgical therapy outcome in terms of tooth loss need to be further addressed in future studies.

Surgical therapy aims at the elimination of periodontal pockets and creating an opportunity for tissue regeneration. Several intervention studies included in the present appraisal have applied regenerative techniques such as GTR membranes and/or allografts.[120-122,124,126-129] In spite of their diversity regarding surgical modality, endpoint selection and follow-up length, the surgical therapy intervention studies consistently point to an inferior outcome in smokers compared with nonsmokers. As with nonsurgical studies, most of the surgical studies use *average changes* in PPD, CAL, and/or PBL as the endpoint(s) of choice. Studies where the outcome is evaluated on the basis of criteria for success or failure, unfortunately, are few and use widely different criteria.[109,120,126,127] Furthermore, only one of these studies evaluates the outcome after more than 1 year.[109] There is a need for extended surgical as well as nonsurgical therapy intervention studies for a better understanding of the long-term effects of smoking on tooth survival.

On the basis of the present analysis that

> 91% of 10 nonsurgical and 93% of 14 surgical therapy intervention studies indicate an untoward effect of smoking on the therapeutic outcome,

it is concluded that there is limited but consistent evidence to suggest that smoking negatively interferes with the therapy outcomes of nonsurgical as well as surgical interventions. Thus, there is fair evidence to recommend that smoking be specifically considered in a periodontal therapy intervention (Recommendation grade B-C).

REFERENCES

1. Bergstrom J, Floderus-Myrhed B. Co-twin control study of the relationship between smoking and some periodontal disease factors. Community Dent Oral Epidemiol 1983;11:113-6.
2. Feldman RS, Bravacos JS, Rose CL. Association between smoking different tobacco products and periodontal disease indexes. J Periodontol 1983;54:481-7.
3. Ismail AI, Burt BA, Eklund SA. Epidemiologic patterns of smoking and periodontal disease in the United States. J Am Dent Assoc 1983;106: 617-21.
4. Albandar J, Streckfus CM, Adesanya MR, Winn DM. Cigar, pipe and cigarette smoking as risk factors for periodontal disease and tooth loss. J Periodontol 2000;71:1874-81.
5. Amarasena N, Ekanayaka A, Herath L, Miyazaki H. Tobacco use and oral hygiene as risk indicators for periodontitis. Community Dent Oral Epidemiol 2002;30:115-23.
6. Amarasena N, Ekanayaka A, Herath L, Miyazaki H. Association between smoking, betel chewing and and gingival bleeding in rural Sri Lanka. J Clin Periodontol 2003;30:403-8.
7. Axelsson P, Paulander J, Lindhe J. Relationship between smoking and dental status in 35-, 50-, 65-, and 75-year-old individuals. J Clin Periodontol 1998;25:297-305.
8. Bergstrom J, Eliasson S. Noxious effect of cigarette smoking on periodontal health. J Periodont Res 1987;22:513-7.
9. Bergstrom J, Eliasson S. Cigarette smoking and alveolar bone height in subjects with a high standard of oral hygiene. J Clin Periodontol 1987; 14:466-9.

10. Bergstrom J, Eliasson S, Preber H. Cigarette smoking and periodontal bone loss [published erratum appears in J Periodontol 1991; 62:809]. J Periodontol 1991;62:242-6.
11. Bergstrom J, Eliasson S, Dock J. Exposure to tobacco smoking and periodontal health. J Clin Periodontol 2000;27:61-8.
12. Bergstrom J. Tobacco smoking and risk for periodontal disease. J Clin Periodontol 2003;30:107-13.
13. Bridges RB, Anderson JW, Saxe SR, Gregory K, Bridges SR. Periodontal status of diabetic and non-diabetic men: effects of smoking, glycemic control, and socioeconomic factors. J Periodontol 1996;67: 1185-92.
14. Craig R, Boylan R, Yip J, Bamgboye P, Koutsoukos J, Mijares D, et al. Prevalence and risk indicators for destructive periodontal diseases in 3 urban American minority populations. J Clin Periodontol 2001;28: 524-35.
15. Do GL, Spencer AJ, Roberts-Thomson K, Ha DH. Smoking as a risk indicator for periodontal disease in the middle-aged Vietnamese population. Community Dent Oral Epidemiol 2003;31:437-46.
16. Dolan TA, Gilbert GH, Ringelberg ML, Legler DW, Antonson DE, Foerster U, et al. Behavioral risk indicators of attachment loss in adult Floridians. J Clin Periodontol 1997;24:223-32.
17. Dye B, Selwitz R. The relationship between selected measures of periodontal status and demographic and behavioural risk factors. J Clin Periodontol 2005;32:798-808.
18. Goultschin J, Cohen HD, Donchin M, Brayer L, Soskolne WA. Association of smoking with periodontal treatment needs. J Periodontol 1990;61:364-7.
19. Grossi SG, Genco RJ, Machtei EE, Ho AW, Koch G, Dunford R, et al. Assessment of risk for periodontal disease. II. Risk indicators for alveolar bone loss. J Periodontol 1995;66:23-9.
20. Grossi SG, Skrepcinski FB, DeCaro T, Zambon JJ, Cummins D, Genco RJ. Response to periodontal therapy in diabetics and smokers. J Periodontol 1996;67:1094-102.
21. Gunsolley JC, Quinn SM, Tew J, Gooss CM, Brooks CN, Schenkein HA. The effect of smoking on individuals with minimal periodontal destruction. J Periodontol 1998;69:165-70.
22. Haber J, Wattles J, Crowley M, Mandell R, Joshipura K, Kent RL. Evidence for cigarette smoking as a major risk factor for periodontitis. J Periodontol 1993;64:16-23.
23. Haffayee A, Socransky S. Relationship of cigarette smoking to attachment level profiles. J Clin Periodontol 2001;28:283-95.
24. Hansen BF, Bjertness E, Gronnesby JK. A socio-ecologic model for periodontal diseases. J Clin Periodontol 1993;20:584-90.
25. Hildebolt CF, Pilgram TK, Dotson M, Yokoyama-Crothers N, Muckerman J, Hauser J, et al. Attachment loss with postmenopausal age and smoking. J Periodont Res 1997;32:619-25.
26. Horning GM, Hatch CL, Cohen ME. Risk indicators for periodontitis in a military treatment population. J Periodontol 1992;63:297-302.
27. Hyman J, Reid B. Epidemiologic risk factors for periodontal attachment loss among adults in the United States. J Clin Periodontol 2003;30:230-7.
28. Jette AM, Feldman HA, Tennstedt SL. Tobacco use: a modifiable risk factor for dental disease among the elderly. Am J Public Health 1993; 83:1271-6.
29. Khader Y, Rice J, Lefante J. Factors associated with periodontal diseases in a dental teaching clinic population in northern Jordan. J Periodontol 2003;74:1610-7.
30. Kocher T, Schwan C, Gesch D, Bernhardt O, John U, Meisel P, et al. Risk determinants of periodontal disease—an analysis of the study of health in Pomerania (SHIP 0). J Clin Periodontol 2005;32: 59-67.
31. Linden GJ, Mullally BH. Cigarette smoking and periodontal destruction in young adults. J Periodontol 1994;65:718-23.
32. Locker D, Leake JL. Risk indicators and risk markers for periodontal disease experience in older adults living independently in Ontario, Canada. J Dent Res 1993;72:9-17.
33. Loos B, Roos M, Schellekens P, Velden U, Miedema F. Lymphocyte numbers and function in relation to periodontitis and smoking. J Periodontol 2004;75:557-64.
34. Machuca G, Rosales I, Lacalle JR, Machuca C, Bullon P. Effect of cigarette smoking on periodontal status of healthy young adults. J Periodontol 2000;71:73-8.
35. Markkanen H, Paunio I, Tuominen R, Rajala M. Smoking and periodontal disease in the Finnish population aged 30 years and over. J Dent Res 1985;64:932-5.
36. Martinez-Canut P, Lorca A, Magan R. Smoking and periodontal disease severity. J Clin Periodontol 1995;22:743-9.
37. Meisel P, Siegemund A, Grimm R, Herrmann FH, John U, Schwan C, et al. The interleukin-1 polymorphism, smoking and the risk of periodontal disease in the population-based SHIP study. J Periodont Res 2003;82:189-93.
38. Meisel P, Schwan C, Gesch D, Bernhardt O, John U, Kocher T. Dose-effect relation of smoking and the interleukin-1 gene polymorphism in periodontal disease. J Periodontol 2004;75:236-42.
39. Moore PA, Weyant RJ, Mongelluzzo MB, Myers DE, Rossie K, Guggenheimer J, et al. Type 1 diabetes mellitus and oral health: assessment of periodontal disease. J Periodontol 1999;70:409-17.
40. Mullally BH, Linden GJ. Molar furcation involvement associated with cigarette smoking in periodontal referrals. J Clin Periodontol 1996;23: 658-61.
41. Nakashima K, Kobayashi T, Yoshihara A, Fujiwara J, Miyazaki H, Kowashi Y. Periodontal conditions in an elderly Japanese population influenced by smoking status and serum immunoglobulin G2 levels. J Periodontol 2005;76:582-9.
42. Natto S, Baljoon M, Bergstrom J. Tobacco smoking and periodontal health in a Saudi Arabian population. J Periodontol 2005;76: 1919-26.
43. Nishida N, Tanaka M, Hayashi N, Nagata H, Takeshita T, Nakayama K, et al. Determination of smoking and obesity as periodontitis risks using the classification and regression tree method. J Periodontol 2005; 76:923-8.
44. Norderyd O, Hugoson A. Risk of severe periodontal disease in a Swedish adult population. A cross-sectional study. J Clin Periodontol 1998;25:1022-8.
45. Natto S, Baljoon M, Bergstrom J. Tobacco smoking and periodontal bone height in a Saudi Arabian population. J Clin Periodontol 2005;32: 1000-6.
46. Osterberg T, Mellstrom D. Tobacco smoking, a major risk factor for loss of teeth in three 70-year-old cohorts. Community Dent Oral Epidemiol 1986;14:367-670.
47. Paidi S, Pack AR, Thomson WM. An example of measurement and reporting of periodontal loss of attachment (LOA) in epidemiological studies: smoking and periodontal tissue destruction. N Z Dent J 1999; 95:118-23.
48. Persson RE, Hollender LG, Persson GR. Assessment of alveolar bone levels from intraoral radiographs in subjects between ages 15 and 94 years seeking dental care. J Clin Periodontol 1998;25:647-54.
49. Persson RE, Kiyak AH, Wyatt C, MacEntee M, Persson GR. Smoking a weak predictor of periodontitis in older aadults. J Clin Periodontol 2005;32:512-7.
50. Quinn SM, Zhang JB, Gunsolley JC, Schenkein HA, Tew JG. The influence of smoking and race on adult periodontitis and serum Ig G2 levels. J Periodontol 1998;69:171-7.
51. Ragnarsson E, Eliasson S, Olafsson S. Tobacco smoking, a factor in tooth loss in Reykjavik, Iceland. Scand J Dent Res 1992;100:322-6.
52. Razali, Palmer R, Coward P, Wilson RF. A retrospective study of periodontal disease severity in smokers and non-smokers. Br Dent J 2005;198:495-8.
53. Sbaraglia M, Turnbull RS, Locker D. Risk indicators for periodontal disease in a remote Canadian community—a dental practice-based study. J Public Health Dent 2002;62:51-6.
54. Schenkein HA, Gunsolley JC, Koertge TE, Schenkein JG, Tew JG. Smoking and its effects on early-onset periodontitis. J Am Dent Assoc 1995;126:1107-13.

55. Sheiham A. Periodontal disease and oral cleanliness in tobacco smokers. J Periodontol 1971;42:259-63.
56. Solomon HA, Priore RL, Bross ID. Cigarette smoking and periodontal disease. J Am Dent Assoc 1968;77:1081-4.
57. Stoltenberg JL, Osborn JB, Pihlstrom BL, Herzberg MC, Aeppli DM, Wolff LF, et al. Association between cigarette smoking, bacterial pathogens, and periodontal status. J Periodontol 1993;64: 1225-30.
58. Summers CJ, Oberman A. Association of oral disease with 12 selected variables. I. Periodontal disease. J Dent Res 1968;47:457-62.
59. Susin C, Dalla Vecchia C, Oppermann RV, Haugejorden O, Albandar JM. Periodontal attachment loss in an urban population of Brazilian adults: effect of demographic, behavioural, and environmental risk indicators. J Periodontol 2004;75:1033-41.
60. Susin C, Haas A, Oppermann RV, Haugejorden O, Albandar JM. Gingival recession: epidemiology and risk indicators in a representative urban Brazilian population. J Periodontol 2004;75:1377-86.
61. Susin C, Valle P, Oppermann RV, Haugejorden O, Albandar JM. Occurrence and risk indicators of increased probing depth in an adult Brazilian population. J Clin Periodontol 2005;32:123-9.
62. Susin C, Oppermann RV, Haugejorden O, Albandar JM. Tooth loss and associated risk indicators in an adult urban population from south Brazil. Acta Odontol Scand 2005;63:85-93.
63. Tanaka K, Miyake Y, Sasaki S, Ohya Y, Miyamoto S, Matsunaga I, et al. Active and passive smoking and tooth loss in Japanese women: baseline data from the Osaka maternal and child health study. Ann Epidemiol 2005;15:358-64.
64. Tomar S, Asma S. Smoking-attributable periodontitis in the United States: findings from NHANES III. J Periodontol 2000;71:743-51.
65. Torrungruang K, Tamsailom S, Rojanasomsith K, Sutdhibhisal S, Nisapakultorn K, Vanichiakvong O, et al. Risk indicators of periodontal disease in older Thai adults. J Periodontol 2005;76:558-65.
66. Torrungruang, Nisapakultorn K, Sutdhibhisal S, Tamsailom S, Rojanasomsith K, Vanichiakvong O, et al. The effect of cigarette smoking on the severity of periodontal disease among older Thai adults. J Periodontol 2005;76:566-72.
67. Unell L, Soderfeldt B, Halling A, Birkhed D. Explanatory models for clinical and subjective indicators of periodontal disease in an adult population. J Clin Periodontol 2000;27:22-9.
68. Wakai K, Kawamura T, Umemura O, Hara Y, Machida J, Anno T, et al. Associations of medical status and physical fitness with periodontal disease. J Clin Periodontol 1999;26:664-72.
69. Ylostalo P, Sakki T, Laitinen J, Jarvelin M-R, Knuuttilla M. The relation of tobacco smoking etc. Eur J Oral Sci 2004;112:121-6.
70. Yoshida Y, Hatanaka Y, Imaki M, Ogawa Y, Miyatani S, Tanada S. Epidemiological study on improving the QOL and oral conditions of the aged. Par 2: Relationship between tooth loss and lifestyle factors for adult men. J Physiol Anthropol 2001;20:369-73.
71. Al-Wahadni, Linden G. The effects of smoking on the periodontal condition of young Jordanian adults. J Clin Periodontol 2003;30:132-7.
72. Bergstrom J. Cigarette smoking as risk factor in chronic periodontal disease. Community Dent Oral Epidemiol 1989;17:245-7.
73. Calsina G, Ramon J-M, Echeverria J-J. Effects of smoking on periodontal tissues. J Clin Periodontol 2002;29:771-6.
74. Haber J, Kent RL. Cigarette smoking in a periodontal practice. J Periodontol 1992;63:100-6.
75. Kerdvongbundit V, Wikesjo UM. Effect of smoking on periodontal health in molar teeth. J Periodontol 2000;71:433-7.
76. Kerdvongbundit V, Wikesjo UM. Prevalence and severity of periodontal disease at mandibular molar teeth in smokers with regular oral hygiene habits. J Periodontol 2000;73:735-40.
77. MacFarlane GD, Herzberg MC, Wolff LF, Hardie NA. Refractory periodontitis associated with abnormal polymorphonuclear leukocyte phagocytosis and cigarette smoking. J Periodontol 1992;63:908-13.
78. Meinberg T, Canarsky-Handley A, McClenahan A, Poulsen D, Marx D, Reinhardt R. Outcomes associated with supportive periodontal therapy in smokers and non-smokers. J Dent Hygiene 2001;75:15-9.
79. Meisel P, Siegemund A, Dombrowa S, Sawaf H, Fanghaenel J, Kocher T. Smoking and polymorphisms of the interleukin-1 cluster in patients with periodontal disease. J Periodontol 2002;73:27-32.
80. Molloy J, Wolff LF, Lopez-Guzman A, Hodges JS. The association of periodontal disease parameters with systemic medical conditions and tobacco use. J Clin Periodontol 2004;31:625-32.
81. Monteiro da Silva AM, Newman HN, Oakley DA, O'Leary R. Psychosocial factors, dental plaque levels and smoking in periodontitis patients. J Clin Periodontol 1998;25:517-23.
82. Mullally BH, Breen B, Linden GJ. Smoking and patterns of bone loss in early-onset periodontitis. J Periodontol 1999;70:394-401.
83. Preber H, Bergstrom J. Cigarette smoking in patients referred for periodontal treatment. Scand J Dent Res 1986;94:102-8.
84. Syrjala A-M, Ylostalo P, Niskanen M, Knuuttila M. Role of smoking and HbA1c level in periodontitis among insulin-dependent diabetic patients. J Clin Periodontol 2003;30:871-5.
85. Teng H-C, Lee C-H, Hung H-C, Tsai C-C, Chang Y-Y, Yang Y-H, et al. Lifestyle and psychosocial factors associated with chronic periodontitis in Taiwanese adults. J Periodontol 2003;74:1169-75.
86. Baljoon M, Natto S, Bergstrom J. Long-term effect of smoking on vertical periodontal bone loss. J Clin Periodontol 2005;32:789-97.
87. Beck JD, Cusmano L, Green-Helms W, Koch GG, Offenbacher S. A 5-year study of attachment loss in community-dwelling older adults: incidence density. J Periodontal Res 1997;32:506-15.
88. Bergstrom J, Eliasson S, Dock J. A 10-year prospective study of tobacco smoking and periodontal health. J Periodontol 2000;71: 1338-47.
89. Bergstrom J. Influence of tobacco smoking on periodontal bone height. Long-term observations and a hypothesis. J Clin Periodontol 2004;31: 260-6.
90. Bolin A, Eklund G, Frithiof L, Lavstedt S. The effect of changed smoking habits on marginal alveolar bone loss. A longitudinal study. Swed Dent J 1993;17:211-6.
91. Bostrom L, Linder LE, Bergstrom J. Influence of smoking on the outcome of periodontal surgery. A 5-year follow-up. J Clin Periodontol 1998;25:194-201.
92. Copeland LB, Krall EA, Brown LB, Garcia RI, Streckfus CF. Predictors of tooth loss in two US adult populations. J Public Health Dent 2004;64:31-7.
93. Faddy MJ, Cullinan MP, Palmer JE, Westerman B, Seymour GJ. Ante-dependence modeling in a longitudinal study of periodontal disease: the effect of age, gender, and smoking status. J Periodontol 2000;71:454-9.
94. Feldman RS, Alman JE, Chauncey HH. Periodontal disease indexes and tobacco smoking in healthy aging men. Gerodontics 1987;3:43-6.
95. Hashim R, Thomson WM, Pack A. Smoking in adolescence as a predictor of early loss of periodontal attachment. Community Dent Oral Epidemiol 2001;29:130-5.
96. Holm G. Smoking as an additional risk for tooth loss. J Periodontol 1994;65:996-1001.
97. Ismail AI, Morrison EC, Burt BA, Caffesse RG, Kavanagh MT. Natural history of periodontal disease in adults: findings from the Tecumseh Periodontal Disease Study, 1959-87. J Dent Res 1990;69:430-5.
98. Jansson L, Lavstedt S. Influence of smoking on marginal bone loss and tooth loss—a prospective study over 20 years. J Clin Periodontol 2002; 29:750-6.
99. Krall EA, Garvey AJ, Garcia RI. Alveolar bone loss and tooth loss in male cigar and pipe smokers. J Am Dent Ass 1999;130:57-64.
100. Machtei EE, Dunford R, Hausmann E, Grossi SG, Powell J, Cummins D, et al. Longitudinal study of prognostic factors in established periodontitis patients. J Clin Periodontol 1997;24:102-9.
101. Norderyd O, Hugoson A, Grusovin G. Risk of severe periodontal disease in a Swedish adult population. A longitudinal study. J Clin Periodontol 1999;26:608-15.
102. Ogawa H, Yoshihara A, Hirotomi T, Ando Y, Miyazaki H. Risk factors for periodontal disease progression among elderly people. J Clin Periodontol 2002;29:592-7.

103. Paulander J, Wennstrom J, Axelsson P, Lindhe J. Some risk factors for periodontal bone loss in 50-year-old individuals. J Clin Periodontol 2004;31:489-96.
104. Payne JB, Reinhardt RA, Nummikoski PV, Dunning DG, Patil KD. The association of cigarette smoking with alveolar bone loss in postmenopausal females. J Clin Periodontol 2000;27:658-64.
105. Skaleric U, Kovac-Kavcic M. Some risk factors for the progression of periodontal disease. J Intern Acad Periodontol 2000;2/1:19-23.
106. Thomson W, Slade G, Beck J, Elter J, Spencer J, Chalmers J. Incidence of periodontal attachment loss over 5 years among older South Australians. J Clin Periodontol 2004;31:119-25.
107. Yoshihara A, Sugita N, Yamamoto K, Kobayashi T, Hirotomi T, Ogawa H, et al. Fc*F*RIIIb genotypes and smoking in periodontal disease progression among community-dwelling older adults in Japan. J Periodontol 2005;76:250-5.
108. Ah MK, Johnson GK, Kaldahl WB, Patil KD, Kalkwarf KL. The effect of smoking on the response to periodontal therapy. J Clin Periodontol 1994;21:91-7.
109. Fardal O, Johannessen AG, Linden GJ. Tooth loss during maintenance following periodontal treatment in a periodontal practice in Norway. J Clin Periodontol 2004;31:550-5.
110. Kamma J, Baehni P. Five-year maintenance follow-up of early-onset periodontitis patients. J Clin Periodontol 2003;30:562-72.
111. Kinane DF, Radvar M. The effect of smoking on mechanical and antimicrobial periodontal therapy. J Periodontol 1997;68:467-72.
112. Palmer RM, Matthews JP, Wilson RF. Non-surgical periodontal treatment with and without adjunctive metronidazole in smokers and non-smokers. J Clin Periodontol 1999;26:158-63.
113. Papantonopoulos GH. Smoking influences decision making in periodontal therapy: a retrospective clinical study. J Periodontol 1999;70:1166-73.
114. Preber H, Bergstrom J. The effect of non-surgical treatment on periodontal pockets in smokers and non-smokers. J Clin Periodontol 1985;13:319-23.
115. Preber H, Linder LE, Bergstrom J. Periodontal healing and periopathogenic microflora in smokers and non-smokers. J Clin Periodontol 1995;22:946-52.
116. Preshaw PM, Hefti AF, Bradshaw MH. Adjunctive subantimicrobial dose doxycycline in smokers and non-smokers with chronic periodontitis. J Clin Periodontol 2005;32:610-2.
117. Renvert S, Dahlen G, Wikstrom M. The clinical and microbiological effects of non-surgical periodontal therapy in smokers and non-smokers. J Clin Periodontol 1998;25:153-7.
118. Rieder C, Joss A, Lang N. Influence of compliance and smoking habits on the outcome of supportive periodontal therapy (SPT) in a private practice. Oral Health Prev Dent 2005;2:89-94.
119. Ryder MI, Pons B, Adams D, Beiswanger B, Blanco V, Bogle G, et al. Effects of smoking on local delivery of controlled-release doxycycline as compared to scaling and root planing. J Clin Periodontol 1999;26: 683-91.
120. Ehmke B, Rudiger SG, Hommens A, Karch H, Flemmig TF. Guided tissue regeneration using a polylactic acid barrier. J Clin Periodontol 2003;30:368-74.
121. Loos B, Louwerse P, Winkelhoff A, Burger W, Gilijamse M, Hart A, Velden U. Use of barrier membranes and systemic antibiotics in the treatment of intraosseous defects. J Clin Periodontol 2002;29:910-21.
122. Luepke PG, Mellonig JT, Brunsvold MA. A clinical evaluation of a bioresorbable barrier with and without decalcified freeze-dried bone allograft in the treatment of molar furcations. J Clin Periodontol 1997; 24:440-6.
123. Preber H, Bergstrom J. Effect of cigarette smoking on periodontal healing following surgical therapy. J Clin Periodontol 1990;17:324-8.
124. Rosen PS, Marks MH, Reynolds MA. Influence of smoking on long-term clinical results of intrabony defects treated with regenerative therapy. J Periodontol 1996;67:1159-63.
125. Scabbia A, Cho K-S, Sigurdsson T, Kim C-K, Trombelli L. Cigarette smoking negatively affects healing response following flap debridement surgery. J Periodontol 2001;72:43-9.
126. Stavropoulos A, Mardas N, Herrero F, Karring T. Smoking affects the outcome of guided tissue regeneration with bioresorbable membranes: a retrospective analysis of intrabony defects. J Clin Periodontol 2004; 31:945-50.
127. Tonetti MS, Pini-Prato G, Cortellini P. Effect of cigarette smoking on periodontal healing following GTR in infrabony defects. A preliminary retrospective study. J Clin Periodontol 1995;22:229-34.
128. Trombelli L, Kim CK, Zimmerman GJ, Wikesjo UM. Retrospective analysis of factors related to clinical outcome of guided tissue regeneration procedures in intrabony defects. J Clin Periodontol 1997;24:366-71.
129. Trombelli L, Minenna L, Farina R, Scabbia A. Guided tissue regeneration in human gingival recessions. A 10-year follow-up study. J Clin Periodontol 2005;32:16-20.