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Some risk factors for periodontal bone loss in 50-year-old individuals

A 10-year cohort study

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Abstract

Objective: The aim of this 10-year prospective study of 50-year-old individuals was to analyze the incidence of periodontal bone loss and potential risk factors for periodontal bone loss.

Methods: The subject sample was generated from an epidemiological survey performed in 1988 of subjects living in the County of Värmland, Sweden. A randomized sample of 15% of the 50-year-old inhabitants in the county was drawn. At the 10-year follow-up in 1998, 320 (75%) of the 449 individuals examined at baseline were available for re-examination, out of which 4 had become edentulous. Full-mouth clinical and radiographic examinations and questionnaire surveys were performed in 1988 and 1998. Two hundred and ninety-five individuals (69%) had complete data for inclusion in the analysis of radiographic bone changes over 10 years. Non-parametric tests, correlations and stepwise multiple regression models were used for statistical analysis of the data.

Results: The mean alveolar bone level (ABL) in 1988 was 2.2 mm (0.05) and a further 0.4 mm (0.57) ($p = 0.000$) was lost over the 10 years. Eight percent of the subject sample showed no loss, while 5% experienced a mean bone loss of $\geqslant 1$ mm. Smoking was found to be the strongest individual risk predictor (RR = 3.2; 95% CI 2.03–5.15). When including as smokers only those individuals who had continued with the habit during the entire 10-year follow-up period, the relative risk was slightly increased (3.6; 95% CI 2.32–5.57). Subjects who had quit smoking before the baseline examination did not demonstrate a significantly increased risk for disease progression (RR = 1.3; 95% CI 0.57–2.96). Stepwise multiple regression analysis revealed that smoking, % approximal sites with probing pocket depth $\geqslant 4$ mm, number of teeth and systemic disease were significant explanatory factors for 10-year ABL loss ($R^2 = 0.12$). For never smokers, statistically significant predictors were number of teeth, mean ABL, % periodontally healthy approximal sites and educational level ($R^2 = 0.20$).

Conclusion: The inclusion of smokers in risk analysis for periodontal diseases may obstruct the possibility to detect other true risk factors and risk indicators.

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Findings from epidemiological studies are important to planners of oral health care programs because they may provide information regarding, for example, periodontal disease and identify circumstances or variables that may be related to or be causal to the disease (Albandar & Thomas 2002). Data generated from cross-sectional studies will present information about the prevalence of a given disease and its association to different sets of variables. By the use of prospective longitudinal studies on defined cohorts, the incidence of disease progression can be determined. Hence, with the utilization of the cohort study design, risk prediction as well as identification of both associative risk indicators and modifying risk factors is feasible (Kingman & Albandar 2002).

Available data from longitudinal studies on the progression of destructive periodontal disease indicate that the rate of periodontal tissue destruction in a non-stratified population is low (Albandar et al. 1986, Papapanou et al. 1989, Wennström et al. 1993, Hugoson & Laurell 2000, Jansson et al. 2002a,b). Furthermore, advanced forms of destructive periodontal disease commonly occur in comparatively few individuals (Hugoson & Jordan 1982, Lindhe et al. 1983, Löe et al. 1986, Papapanou et al. 1989, Albandar 1990, Axelsson et al. 2000) and tooth sites (Goodson et al. 1982, Lindhe et al. 1989b, Albandar 1990) although the incidences tend to increase in ages above 50 years (Lindhe et al. 1989a, Wennström et al. 1993, Hugoson & Laurell 2000). Consequently, to allow for a proper statistical inference in an analysis of risk factors for disease progression, comparatively large randomized population samples, examined over extended periods of time, are required. Moreover, in order to diminish the methodological bias in such studies, Kingman & Albandar (2002) recommended the inclusion of all tooth sites in the examination, the use of an index with a low measurement variation and the use of few well-trained examiners.

Risk prediction of periodontal disease progression in epidemiological studies involves statistical measures to compensate for confounding factors. However, in a publication focusing on analysis of periodontal disease as a risk factor for systemic diseases (Hujoel et al. 2002), it was claimed that smoking, due to its strong impact on general health as well as on periodontal disease, cannot be fully compensated for and, therefore, risk evaluation should be performed on never-smokers only. Whether the same argument may be true also for other risk indicators and risk factors has to our knowledge so far not been analyzed.

In 1988, a random sample of the population in the county of Värmland, Sweden, stratified with regard to age, was clinically and radiographically examined to provide a description of the periodontal status in this population (Axelsson et al. 1998). All dentate 50-year-old individuals at that time (1988) were invited for a follow-up examination after 10 years to determine longitudinal changes that had occurred in the periodontal variables studied. The aim of the present study of the dentate 50-year-old individuals was to analyze (i) the incidence of periodontal bone loss over the 10-year period and (ii) potential risk factors for additional periodontal bone loss.

Material and Methods

The subject sample included in the present study was generated from an epidemiological survey performed in 1988 of subjects living in the County of Värmland, Sweden (Axelsson et al. 1998). A randomized, stratified sample comprising 15% of the approximately 3400 inhabitants who were 50 years old in the county was identified based on randomly generated numbers. The sampling was stratified with respect to urban/rural living–50% of the subjects were living in an urban area ($\approx$ 100,000 inhabitants) and 50% were living in 4 rural areas ($<$8000 inhabitants). All subjects of the population sample ($n = 510$) were invited for a clinical and radiographic examination in 1988, out of which 449 (88%) agreed to participate. The most common reasons, indicated by the remaining 61 invitees (12%), for not being available for the examination were ''no longer living in the area'' or ''severe illness''. The study was reviewed and approved by the Research Ethic Committee at the County of Örebro. All subjects signed a written informed consent regarding their participation in the examinations.

The baseline examination revealed that 20 individuals were edentulous, which resulted in a total sample of 429 dentate subjects to be involved in the planned longitudinal study with follow-up examinations after 5 and 10 years. At the 10-year follow-up interval, 320 of the subjects (75%) were available for re-examination. Twelve of the 109 subjects lost to the 10-year follow-up examination were deceased (11%), 8 were not able to participate due to severe illness (7%), 18 had moved from the area (17%), 55 refused to participate (50%), and 16 did not respond to the invitation (15%).

For the radiographic evaluation of periodontal bone changes, the subject sample available for analysis was further reduced due to missing radiographs ($n = 13$) or lack of valid reference points for bone level assessments in the radiographs ($n = 8$). In addition, 4 of the re-examined 320 subjects had become edentulous during the 10-year interval of follow-up. Hence, the final subject sample comprised 295 individuals, that is, 69% of the originally examined 429 dentate subjects at baseline (Fig. 1). The cohort consisted of 145 urban and 150 rural residents; the proportion of males to women was 131/164, that is, figures that were similar to those of the original population sample examined in 1988. Seventy-eight individuals (27%) were smokers while 179 (61%) claimed that they had never smoked on a regular basis.

Clinical examinations

The clinical examinations were performed in a Public Dental Health clinic, using a conventional dental unit and illumination. Four well-trained and calibrated dentists performed the examinations in 1988 and 1993. Before each examination period, a training session was carried out in order to calibrate the examiners with respect to the various assessments included in the examinations. Only one of original examiners could participate in the examination in 1998 and three new examiners were therefore trained and calibrated to the remaining experienced examiner.

At each of the three examination intervals, the following clinical variables were recorded (third molars excluded):

- *Remaining teeth:* The number and type of teeth were determined. Roots remnants were considered as missing teeth.
- *Occlusal contacts:* The antagonistic tooth contact pattern was assessed according to a modification of the simplified Eichner index (Österberg & Landt 1976); score A – antagonistic tooth contacts (natural teeth, implants or fixed dentures) present in all four supportive zones (premolar and molar regions); score B – antagonistic tooth contacts present in $\leqslant 3$ supportive zones.
- *Periodontal treatment needs:* Assessments according to the criteria of the Community Periodontal Index of Treatment Needs (CPITN, Ainamo 1984) were made at all mesial, buccal, distal and lingual surfaces. For the present report, the scores for the proximal sites were used to calculate (i) the percentage of periodontally healthy proximal sites (% CPITN-a 0) and (ii) the percentage

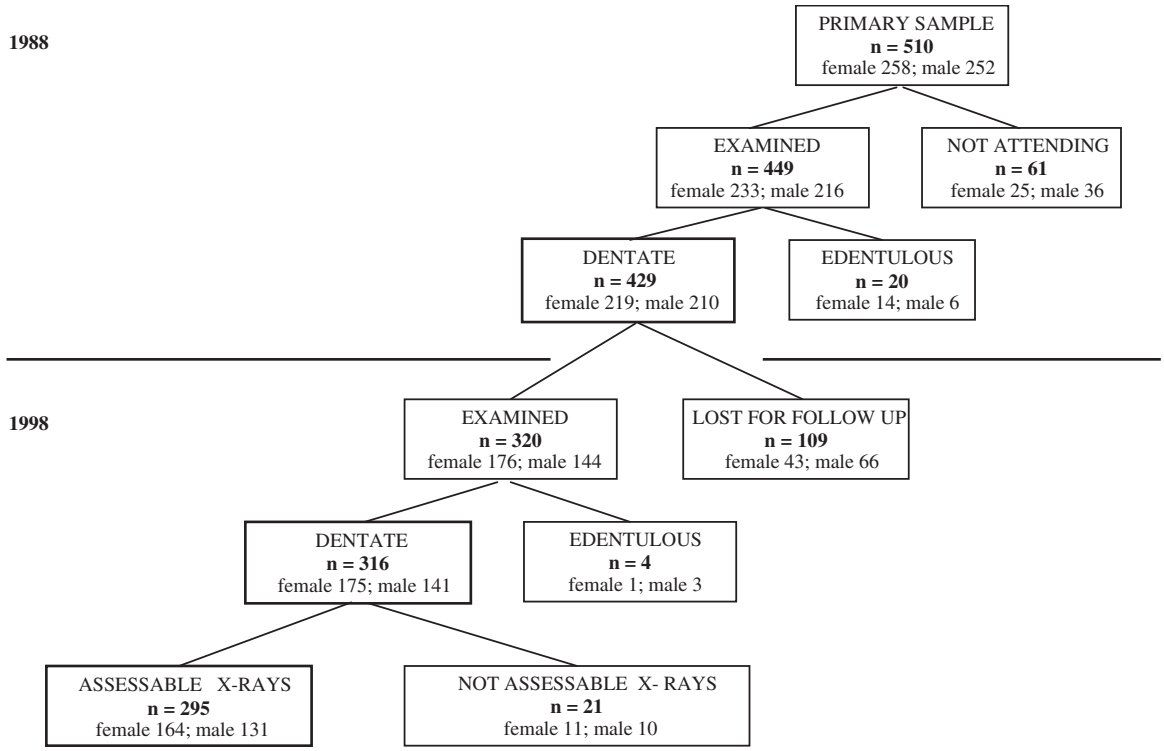

Fig. 1. Description of the subject sample examined.

of proximal sites with probing pocket depth $\geqslant 4$ mm (% CPITN-a 3+4).

- *Oral hygiene:* Dental plaque was visualized by the use of a disclosing solution and scored as present or absent on all mesial, buccal, distal and lingual tooth surfaces. The % of surfaces with plaque was calculated for each subject.

Radiographic assessments

At baseline and at the 10-year follow-up examinations a set of full-mouth intraoral periapical and bitewing radiographs was taken by the use of a standardized parallel technique (Eggen 1969). For all teeth present at the 10-year re-examination (except third molars), mesial and distal tooth sites were examined with respect to *alveolar bone level* (*ABL*). The distance (mm) between the cemento-enamel junction (CEJ) and the most coronal level at which the periodontal ligament space was considered to have a normal width (Björn et al. 1969) was measured using a CAD device and directly stored in a computer (Wennström et al. 1993). For each site, the pair of radiographs that had the best resemblance in projection in 1988 and 1998 was used. Tooth sites at which the CEJ could not be properly identified in the radiographs representing the two time intervals were excluded. One examiner performed all the radiographic measurements.

The error of the method used for recording the radiographic alveolar bone level was assessed through duplicate measurements performed in 6 randomly chosen subjects (258 tooth sites). The mean difference between the measurements was 0.01 mm (SD 0.23) with an intra-class correlation coefficient of 0.985. The variance of the difference between repeated assessments corresponded to 0.07% of the variance for the 10-year alveolar bone level change in the total subject sample.

Questionnaire

At the baseline examination in 1988, the participants were asked to complete a questionnaire comprising 30 closed questions on a variety of items related to potential risk factors for dental diseases. Based on the information provided in the questionnaire, the subjects were categorized in the following groups:

Educational level: (i) low educated individuals (only compulsory school training), or (ii) high educated individuals (more than compulsory school training).

Smoking habits: (i) never smokers, (ii) former smokers (regular smoking for more than 5 years prior to 1988), or (iii) current smokers. Information was also obtained regarding number of cigarettes smoked per day and number of years as smoker.

Systemic disease: A subject was considered positive for this variable in case of cardiovascular disease, diabetes or hormonal disease.

Data analysis

All collected data were transferred to the Statistical Package for the Social Sciences (SPSS®) for data checking, due transformations, description and analysis. The mean ABL value and ABL change for each individual were calculated. The distribution of the mean ABL in 1988 and 1998 as well as the differences in mean ABL change were not normally distributed ($p = 0.000$; Kolmogorov–Smirnov) and therefore non-parametric methods were used for the statistical analysis of these data. Correlation analyses were performed according to Pearson and Spearman depending on variable type. Paired statistics were performed with Wilcoxon signed rank test. Forward stepwise regression analysis was used to evaluate

relationships between various baseline variables and longitudinal periodontal bone loss (ABL change).

Results

Comparison between re-examined and lost subjects

Subjects lost to the 10-year clinical re-evaluation

In comparison with the respondents, the non-respondents did not significantly differ with respect to the mean number of teeth (22.5 versus 23.0; $p > 0.05$) or mean periodontal bone level (2.6 versus 2.4. mm; $p > 0.05$) at the baseline examination in 1988, but included a higher number of males (61% versus 45%; $p = 0.005$). Analysis of the data with respect to factors that might explain the observed difference in gender revealed that male subjects (i) had a higher mortality rate during the 10-year follow-up period (10 men versus 2 women) and (ii) showed less interest in their teeth, as evaluated by the questionnaire.

Subjects lost to the 10-year radiographic re-evaluation

The mean number of remaining teeth was lower in the 21 subjects lost for the 10-year radiographic re-evaluation than that of the final cohort ($n = 295$), both in 1988 (17.6 versus 23.6; $p = 0.002$) and in 1998 (16.1 versus 23.0; $p = 0.001$). In addition, at the baseline examination in 1988, the mean radiographic ABL was significantly larger than that for the final cohort (3.41 versus 2.27 mm; $p = 0.02$), but no statistically significant difference in gender was found. The observed differences were primarily explained by the exclusion of sites without radiographically visible CEJ, which, for example, disqualified subjects with full-arch prosthetic reconstructions to be included.

Tooth loss

The distribution of the individuals according to the number of remaining teeth at baseline and 10-year is shown in Fig. 2. In 1988, the mean number of teeth was 23.6 teeth (SE 0.24) compared to 23.0 (0.27) in 1998, that is, a mean loss in 10-years of 0.66 teeth (0.08) was recorded. Eighty-eight percent of the individuals presented with $\geqslant 20$ teeth in 1988, and 83% in 1998. During the 10-year interval 192 individuals (65%) did not suffer tooth loss, 21% lost one tooth, while a tooth loss of $\geqslant 4$ teeth was observed in 3.4% of the subjects (Table 1).

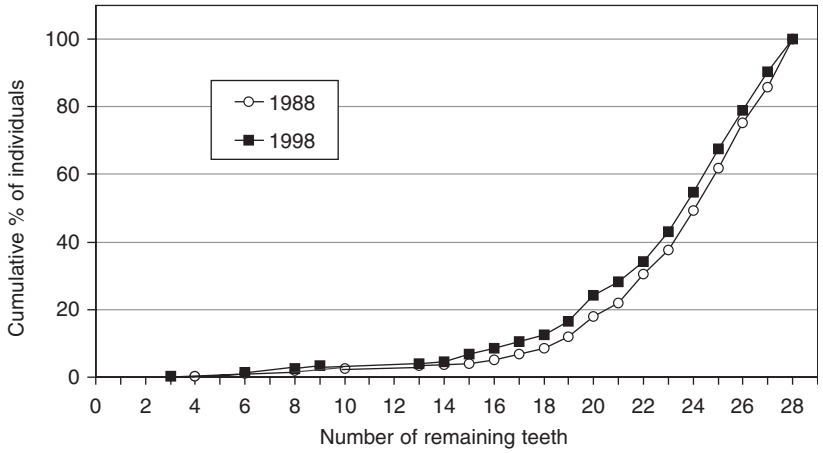

Fig. 2. Cumulative % of subjects according to number of remaining teeth in 1988 and 1998 ($n = 295$).

Table 1. Frequency distribution of the subjects with regard to number of teeth lost during the 10-year interval ($n = 295$)

No. of teeth lost	No. of subjects	%	Cumulative %
0	192	65.1	65.1
1	63	21.4	86.4
2	22	7.5	93.9
3	8	2.7	96.6
4	4	1.4	98.0
6	1	0.3	98.3
7	2	0.7	99.0
9	2	0.7	99.7
10	1	0.3	100.0

Alveolar bone level

On the average 30 (0.66) proximal tooth sites per individual (65% of the total available number of sites) qualified for evaluation of periodontal bone level. The mean ABL in 1988 was 2.2 mm (0.05) and in 1998 2.6 mm (0.06).

In Fig. 3 the distribution of the individuals in relation to mean alveolar bone level (ABL) is presented for the baseline and 10-year follow-up examinations. The frequency of individuals showing a mean ABL of $\leqslant 2$ mm was 47% in 1988 and 32% in 1998. The corresponding figure for a mean ABL of $\geqslant 4$ mm was 3% and 7%, respectively.

Longitudinal Alveolar Bone Loss

The mean bone loss over the 10-year period amounted to 0.4 mm (0.57) ($p = 0.000$). Fig. 4 shows the cumulative % of subjects with respect to the change in mean ABL. Twenty-four individuals (8%) showed no further loss of periodontal bone support, while 5% of the subject sample (14 individuals) experienced a mean bone loss of $\geqslant 1$ mm. The subject with the most advanced loss of periodontal bone support demonstrated a change of 7.6 mm during the 10-year period.

Individuals who lost teeth during the study period showed, compared to the rest of the sample, higher mean ABL at baseline (2.6 mm versus 2.1 mm, $p = 0.001$), and significantly greater bone loss over the 10 years (0.5 mm versus 0.3 mm, $p = 0.001$).

Risk Factors and Risk Indicators for Alveolar Bone Loss

Table 2 describes the results of the correlation analysis performed between parametric variables assessed at baseline and the 10-year change in ABL. A significant negative correlation was found between the number of remaining teeth (-0.211; $p < 0.01$) and % healthy

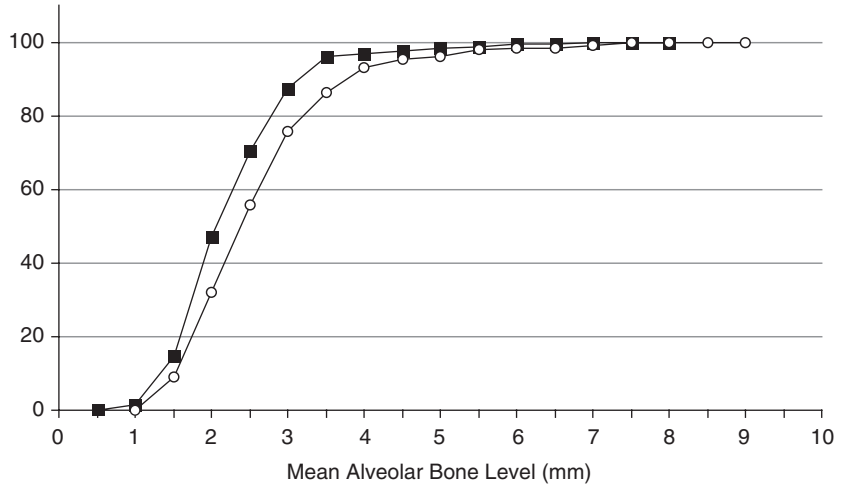

Fig. 3. Cumulative % of subjects according to mean alveolar bone level in 1988 and 1998 ($n = 295$).

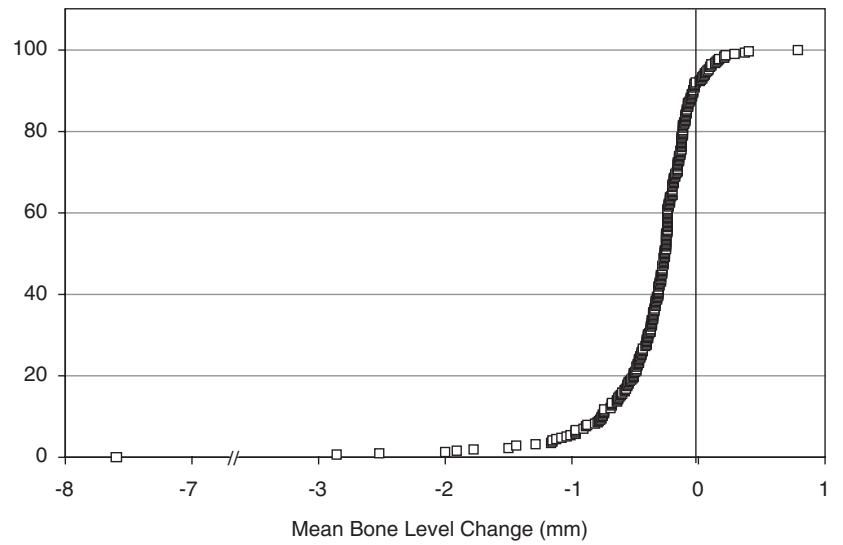

Fig. 4. Cumulative % of subjects according to mean 10-year alveolar bone level change ($n = 295$).

Table 2. Correlation coefficient (Pearson) between continuous variables (1988) and 10-year ABL loss ($n = 295$)

Baseline variables	Correlation coefficient	Sign.
no. of teeth	−0.211	<0.001
% healthy sites	−0.174	<0.01
% sites PPD ⩾4 mm	0.246	<0.001
mean ABL	0.096	NS
plaque %	0.045	NS

proximal periodontal units (%CPITN-a 0; −0.174; $p<0.003$), while % proximal sites with pocket depth ⩾4 mm (%CPITN-a 3+4) showed a positive correlation (0.246, $p<0.000$) to ABL change. The mean ABL and the % of tooth surfaces with dental plaque at baseline were not significantly correlated with the mean change in ABL.

Table 3 presents the results of the correlation analysis that was performed between non-parametric variables recorded at baseline and the 10-year change in ABL. Statistically significant correlations were found for smoking status (0.26; $p<0.01$), educational level (0.12; $p<0.05$) and the modified Eichner Index (0.13; $p<0.05$). Variables such as gender, living area (urban/rural) or ''systemic disease'' were not significantly correlated with ABL change.

Table 4 describes the relative risk (RR) for a subject to show a mean increase of >0.5 mm in ABL during the 10-year period, if he/she scored positive for certain characteristics at baseline. Among the non-parametric variables analyzed, smoking was found to be the strongest risk predictor (RR = 2.73; 95% CI 1.91–3.89). When only individuals who had continued smoking during the entire 10-year follow-up period were included, the relative risk was increased (3.69; 95% CI 2.33–5.85). Subjects who had quit smoking before the baseline examination in 1988 did not demonstrate a significantly increased risk for disease progression (RR = 0.70; 95% CI 0.31–1.59).

Besides smoking, an impaired occlusion (score B) indicated a statistically significantly increased risk for disease progression (RR = 1.38; 95% CI 1.15–1.66), while gender, educational level, living area and ''systemic disease'' were not significantly associated with disease progression. If only individuals who had never smoked were included, no pertinent differences were observed with respect to the relative risk of the various factors.

Two multiple regression models were formulated by a forward stepwise analysis having the individual mean ABL change over the 10-year period as the dependent variable (Tables 5–6). In the first model, including all individuals, the independent variables (i) smoking, (ii) % periodontal pockets ⩾4 mm, (iii) number of remaining teeth and (iv) ''systemic disease'' appeared as statistically significant (Table 5). The standardized coefficients showed that the impact of the independent variables on the 10-year ABL change was of similar magnitude for all 4 variables. However, the coefficient of determination for this particular model was only 0.12.

A similar predictive model including only subjects who had never been smokers revealed that characteristics such as (i) number of remaining teeth, (ii) mean ABL, (iii) % periodontally healthy sites, and (iv) educational level had a statistically significant influence on the 10-year ABL change. The relative contribution of the variables to the observed change in ABL was of similar magnitude (standardized coefficients 0.21–0.28). The coefficient of determination for the final regression model was 0.20.

Discussion

The results of the present 10-year prospective study of a randomly selected subject sample of 50-year-old

Table 3. Correlation coefficient (Spearman's rho) between non-parametric variables and 10-year ABL loss ($n = 295$)

	n	Correlation coefficient	Sign.
smoker (never/former/yes)	179/36/77	0.26	<0.01
educational level (low/high)	137/157	0.12	<0.05
modified Eichner index (0/1)	121/174	0.13	<0.05
systemic disease (no/yes)	48/247	0.10	NS
living area (urban/rural)	145/150	0.01	NS
gender (male/female)	131/164	0.07	NS

Table 4. Relative Risk (RR) including 95% confidence interval for a mean 10-year ABL loss >0.5 mm. *n* = number of cases positive for the risk factor/indicator at baseline (1988)

	n	RR	95% CI
all subjects ($n = 295$)			
smoker 1988	77	2.73	1.91–3.89
smoker 1988–98	53	3.69	2.33–5.85
former smoker	36	0.70	0.31–1.59
reduced Eichner index	174	1.38	1.15–1.66
educational level (low)	137	0.94	0.68–1.28
systemic disease (yes)	48	1.58	0.91–2.75
living area (urban)	145	0.92	0.68–1.24
gender (male)	131	0.95	0.69–1.31
never-smokers only ($n = 179$)			
reduced Eichner index	101	1.37	1.03–1.82
educational level (low)	85	0.90	0.55–1.48
systemic disease (yes)	27	0.85	0.28–2.59
living area (urban)	95	0.98	0.65–1.49
gender (male)	79	1.10	0.69–1.73

Table 5. Forward stepwise multiple regression analysis ($n = 295$)

	Coefficient	SE	Standardized coefficient	*P*-value
constant	0.67	0.193		0.001
Smoker	0.24	0.075	0.185	0.001
% sites PPD ⩾4 mm	0.01	0.002	0.157	0.007
no. of teeth	−0.02	0.008	−0.136	0.016
systemic disease	0.19	0.086	0.123	0.027

Dependent variable: mean 10-year ABL loss. $R^2 = 0.12$.

Table 6. Forward stepwise multiple regression analysis in never-smokers ($n = 179$)

	Coefficient	SE	Standardized coefficient	*p*-Value
constant	0.68	0.156		0.000
no. of teeth	−0.02	0.006	−0.283	0.000
mean ABL	0.10	0.032	0.222	0.001
% healthy sites	0.002	0.001	−0.229	0.001
educational level	0.12	0.041	0.205	0.005

Dependent variable: mean 10-year ABL loss. $R^2 = 0.20$.

individuals demonstrated that (i) smoking, (ii) % approximal sites with probing pocket depth of ⩾4 mm, (iii) number of teeth and (iv) ''systemic disease'' could be identified as significant predictors for alveolar bone loss during a 10-year period. However, if smokers were excluded from the analysis, the only of these characteristics that remained as a significant predictor for further bone loss was ''number of teeth'', and in addition (i) mean alveolar bone level, (ii) % periodontally healthy proximal sites (CPITN score 0), and (iii) educational level entered into the multivariate model as significant predictors.

The subject sample analyzed in this longitudinal study was originally generated by random selection of 15% of 50-year-old individuals living in the county of Värmland, Sweden. Out of 429 dentate subjects who participated in the baseline examination in 1988, 320 (75%) were available for a reexamination 10 years later. This figure of participation is similar to that reported in a number of other longitudinal studies in Sweden (Papapanou et al. 1989, Wennström et al. 1993, Fure & Zickert 1997, Hugoson & Laurell, 2000, Jansson et al. 2002a). Since the non-respondents did not significantly differ with regard to mean number of teeth and mean alveolar bone level at the baseline examination in 1988 compared to those who could be reexamined in 1998, the subject sample included in the final analysis should not be expected to significantly deviate from the original population.

The 50-year-old individuals presented with, on the average, 23.6 teeth at the baseline examination. Fure & Zickert (1997) and Schuller & Holst (1998) examined cohorts of approximately corresponding year of birth and reported 23.5 and 22.5 remaining teeth, respectively. In a study of a randomly selected sample of adult regular dental care attendants performed in 1990 in the same county as involved in the current study, 42–53-year-old individuals had as a mean 24.1 teeth (Wennström et al. 1993), while the number of remaining teeth for the same age group in 1978 was 22.3 teeth. Hence, taken together with the observation in the current study that almost 90% of the 50-year-old subjects had ⩾20 teeth, and findings reported from other national and regional surveys of the dental health in Sweden (e.g. Ahlqwist 1989, Papapanou et al. 1989, Håkansson 1991, Hugoson et al. 1995), a continuous trend to higher number of retained teeth among middle-aged individuals is evident.

In the present sample of initially 50-year-old individuals, on an average 0.7 teeth were lost during the 10-year period of follow-up, and 65% of the individuals did not suffer any tooth loss. This small magnitude of tooth mortality rate is similar to that extrapolated from the longitudinal data reported by Fure & Zickert (1997) (0.8 teeth in 10 years). Wennström et al. (1993) described a tooth mortality rate of 0.9 teeth in 12 years (0.75 teeth/10 years) for initially 42–53-year-old individuals, and with 55% of the subjects showing no tooth loss. In a 20-year longitudinal study

initiated in 1970 involving individuals with a minimum of 5 teeth, Jansson et al. (2002a) observed a mean loss of 4 teeth in 46–55-year-old individuals, that is, 2 teeth/10 years. Hugoson & Laurell (2000) found that 50-year olds who participated in a 17-year longitudinal study, initiated in 1973, had a mean tooth mortality rate of 2.2 teeth, which corresponds to a 10-year loss of 1.4 teeth. Although there is a potential risk that tooth loss during the study period may result in an underestimation of the incidence of periodontal disease progression (Papapanou 1996), it is not likely that the comparatively low rate of tooth loss in the current subject sample should have had a significant influence on the observed rate of periodontal destruction. In fact, a negative correlation was found between the number of teeth present at baseline and the 10-year mean ABL change (-0.211). This indicates that tooth loss was not counteracting the ABL change in the analysis of risk factors.

The radiographic alveolar bone level (ABL) was used to determine the longitudinal change in periodontal status. At the baseline examination, the individual mean ABL was 2.2 mm, and during the 10-year follow-up a mean additional bone loss of 0.4 mm was recorded. In the study by Wennström et al. (1993), which involved regular dental care attendants in the same county as in the present study, the mean alveolar bone level for subjects in the age 42–53 years was 4.0 mm and the reported additional bone loss during a 12-year follow-up period amounted to 0.2 mm.Hence, in comparison to the data reported by Wennström et al. (1993), the current subject sample exhibited less destructive periodontal disease at baseline, but somewhat higher rate of further periodontal tissue loss during the 10 years of monitoring. Lindhe et al. (1989a), Albandar (1990) and Hugoson & Laurell (2000) have reported that there is a tendency for increase in the incidence of disease progression in age groups above 50 years as compared to younger subjects. On the other hand, in the current subject sample the rate of bone loss over a 10-year interval was similar or lower than that reported in other recent longitudinal studies of 50-year old individuals (Hugoson & Laurell 2000, Schuller & Holst 2001, Jansson et al. 2002a).

Data from numerous studies indicate that cigarette smoking is a significant risk factor for periodontal diseases (Beck et al. 1990, Ismail et al. 1990, Locker & Leake, 1993, Bergström & Preber, 1994, Dolan et al. 1997, Machtei et al. 1997, Axelsson et al. 1998, 2000, Tomar & Asma, 2000, Jansson & Lavstedt, 2002). This was also confirmed in the present study, showing a relative risk (RR) of 3.2 for smokers compared to never smokers. The RR was even greater (3.6) for individuals who had continued with their smoking habits throughout the 10-year study period, while cessation of smoking almost leveled the individual's risk for ABL loss to that of subjects who never smoked. Furthermore, in the multiple regression analysis model based on the entire cohort (Table 5), smoking was found to be the strongest predicting factor, although the difference in the standardized coefficients was small and the multivariate model only explained 12% of the variance in mean ABL-change.

To further elucidate the relative role of various risk factors, the statistical analyses were also performed without the inclusion of smokers. Thus, the multiple regression analysis based only on subjects who had never smoked revealed that, in addition to number of remaining teeth, mean ABL, % periodontally healthy sites and educational level had a statistically significant influence on the 10-year ABL change. The finding that predictors other than those identified for the entire sample (Tables 5 and 6) were entered into the model indicates that smokers may hide relevant risk factors. Moreover, a shift in the direction of RR was found for systemic disease and gender in never-smokers. This observation is in agreement with the hypothesis that smoking and systemic diseases may interact in a complicated manner not allowing for proper elimination of confounding (Hujoel 2002). A possible explanation might be that cigarette smoking, apart from exerting a potential direct influence on periodontal disease progression (Palmer et al. 1999), may be a marker for several associated variables, for example, stress, alcohol consumption, impaired economy (Genco et al. 1988, Schumann et al. 2001). Hence, it is evident from the current analyses that the inclusion of a mixed cohort of smokers and never-smokers may preclude the identification of relevant risk factors. Epidemiological studies of periodontal diseases would therefore benefit from a design that involves a primary randomized selection of a subject sample and subsequently a secondary randomization based on the factors of interest, for example, smoking.

Besides smoking, increased percentage of pockets $= 4$ mm and reduced number of remaining teeth, both variables connected to existing periodontal disease, were found to be significant predictors for further incidence of periodontal destruction. From a clinical point of view, these factors supplemented with the significant predictors for health in never smokers, mean ABL and % healthy proximal sites, may be utilized in decision-making with respect to the need of prophylactic measures in order to minimize the progression rate of periodontal destruction.

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