Intra-oral pattern of tooth and periodontal bone loss between the age of 50 and 60 years. A longitudinal prospective study

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Objective: In a 10-year prospective study we analyzed (i) the intra-oral pattern of and (ii) potential risk factors for tooth and periodontal bone loss in 50-year-old individuals. *Methods:* A randomized subject sample of 50-year-old inhabitants in the County of Värmland, Sweden, was examined at baseline and after 10 years. Data from full-mouth clinical and radiographic examinations and questionnaire surveys of 309 (72%) of the individuals who were dentate at baseline were available for analysis. Non-parametric tests and binary logistic multiple regression models were used for statistical analysis of the data. *Results:* 4.1% of the 7,101 teeth present at baseline, distributed among 39% of the subjects, were lost during the 10-year interval. The incidence of tooth loss was highest among mandibular molars (7.5%) and lowest among canines (1.8%). The relative risk (RR) for tooth loss for endodontically compromised teeth was 4.1 and for furcation-involved molars 2.4–6.5, depending on tooth position. Logistic regression analysis identified baseline alveolar bone level (ABL), endodontic conditions, CPITN score (Community Periodontal Index of Treatment Needs), tooth position, caries, and educational level as risk factors for tooth loss. The overall mean 10-year ABL change was −0.54 mm (S.E. 0.01). On a tooth level the ABL change varied between −0.35 mm (mandibular molars) and −0.79 mm (mandibular incisors). Smokers experienced a greater (20–131% depending on tooth type) mean bone loss than non-smokers. The logistic regression model revealed that tooth position, smoking, and probing pocket depth ≥4 mm were risk factors for bone loss of >1 mm. No pertinent differences were observed with respect to risk factors for ABL change in the subgroup of non-smokers compared to the results of the analysis based on the entire subject sample. *Conclusion:* Tooth loss was more common in the molar than in the anterior tooth regions, while periodontal bone loss had a random distribution in the dentition. The predominant risk factors identified with regard to further radiographic bone loss were 'probing pocket depth ≥6 mm' and 'smoking'. □ *Oral epidemiology; periodontal disease; risk factors*

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Data on periodontal disease generated from epidemiological investigations are commonly reported in terms of mean values and frequency distributions of different pertinent variables on a subject level. By limiting the data analysis to the subject level, however, important information regarding the pattern of the disease and tooth-related potential risk factors for disease development and progression may be obscured (1, 2).

A variety of subject-related as well as tooth-related factors may influence the rate of progression of periodontal disease and tooth loss. Hence, on the individual level factors such as age (1–7), educational level (8–10), living conditions (11–13), and smoking (for reviews see 14, 15) were identified as risk variables. On the tooth level, tooth type/position (16–18), calculus (19), caries (20), endodontic conditions (21, 22), previous experience of periodontal bone loss (16, 23, 24), and occlusal load (25, 26) were associated with progressive periodontal disease and tooth loss.

In a 17-year longitudinal study in a Swedish population aged 20 to 60 years (27), it was observed that while generalized bone loss of ≥2 mm was found in only 5% of the subjects, about 80% of the individuals had 1 or more tooth sites with bone loss of this magnitude. Further analysis of the same subject sample (18) revealed that (i) the incidence of bone loss varied within the dentition without any evident pattern of distribution and (ii) the amount of previous bone loss could not be identified as a predictor for further bone loss. The authors also reported that tooth loss was evenly distributed in the maxillary dentition, whereas in the mandible, posterior teeth had the highest mortality rate.

In a recent publication, Paulander et al. (26) presented data from a 10-year longitudinal study on the pattern of periodontal bone loss in a randomized sample of initially 50-year-old individuals. The authors reported that in the 10-year interval there was a mean periodontal bone loss that amounted to 0.4 mm, but also that 8% had retained the bone level unchanged, while 5% had experienced a mean alveolar bone loss of ≥1 mm. Multiple regression analysis revealed that (i) smoking, (ii) systemic disease, (iii) percentage approximal sites with probing pocket depth ≥4 mm, and (iv) number of remaining teeth at baseline were significant explanatory factors for the 10-year bone

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loss on the subject level. In the subgroup of never-smokers, statistically significant predictors were (i) number of teeth, (ii) mean initial alveolar bone height, (iii) percentage periodontally healthy approximal sites, and (iv) educational level. However, in this model, only a comparatively small proportion (12–20%) of the variance in ABL change could be explained. The aim of the present study was to analyze, at the tooth level, the 10-year longitudinal data from this defined cohort with respect to the incidence of, and risk factors for, (i) progressive loss of periodontal bone support and (ii) tooth loss.

Materials and methods

An epidemiological survey was performed in 1988 and included a randomized sample of 15% of the 50-year-old inhabitants in the County of Värmland, Sweden (15). The primary sample consisted of 429 dentate individuals, out of which 320 (75%) were available for a 10-year follow-up examination in 1998. At initiation of the study, as well as at the 10-year follow-up, data were collected through full-mouth clinical and radiographic examinations and questionnaire surveys. Details regarding the sample, variables included in the examinations, and examiner reproducibility were described recently (15, 26). For the present study, which was based on measurements made on radiographs, data from 309 individuals (72%) were included.

Variables

In sets of full-mouth, intra-oral radiographs obtained at baseline (1988) and at the 10-year follow-up examination (1998), the following variables were determined by one examiner (for details see 26):

Remaining teeth: The number and type of teeth.

Alveolar bone level (ABL): Measured in millimetres from the cemento-enamel junction (CEJ) at the mesial and distal aspects of each tooth at baseline (ABL_{88}) and at 10 years (ABL_{98}).

Caries$_{88}$: Surfaces displaying caries lesions, i.e. clinically and/or radiographically identified primary, secondary (recurrent) caries lesions. For each tooth, caries$_{88}$ and the 10-year ABL change were collected from the same approximal surface.

Endodontic condition$_{88}$: Presence of root filling, post and apical radiolucency.

For all subjects, tooth loss over the 10-year interval and ABL change (ABL change; ABL_{88}–ABL_{98}) for each tooth site were determined. The approximal surface with the most pronounced bone loss was selected to represent the individual tooth in the data analysis.

From the data collected at the clinical examination at baseline in 1988 the following variables were considered:

CPITN score$_{88}$: According to the criteria described by Ainamo (28). For each tooth, the CPITN score$_{88}$ and the 10-year ABL change were collected from the same approximal surface.

Furcation involvement$_{88}$: The assessment was made at each furcation entrance of all molars and scored according to the criteria of Hamp et al. (29). The highest score for each tooth was recorded.

In addition, data such as (i) gender, (ii) geographical living area (urban/rural), (iii) educational level (low/high), (iv) smoking habits (non-smoker/smoker), and (v) systemic disease (no/yes) were retrieved (for details 26).

Data analysis

Data-checking, transformations, description and analyses were performed in SPSS (SPSS Inc. Version 11.5). The data describing tooth loss and ABL change for contralateral teeth were collapsed in the analysis, since no statistically significant differences were observed between quadrants. In the analysis of ABL change, only teeth were included that exhibited a well-defined CEJ. Mean values, standard errors (S.E.), frequency distribution, and relative risk (RR) were calculated for data description.

Tooth loss was tested against a binomial distribution assuming a probability of 4.1%, which corresponded to the overall incidence of tooth loss over the 10 years in the subject sample.

In order to identify risk factors for tooth loss, a binary logistic backwards, stepwise regression model was constructed (30). A comparative model with ABL change ($\leq$1 mm or >1 mm) as the dependent variable was formed using a forward stepwise technique. In both models (i) subject characteristics (gender, geographical living area, educational level, smoking habits, systemic disease) identified in a previous analysis of the data (26), and (ii) tooth-related factors (jaw, tooth position, ABL_{88}, *CPITN score$_{88}$*, *caries$_{88}$*, and *endodontic condition$_{88}$*) were introduced as independent variables. A similar binary logistic regression model for ABL change in the subsample of non-smokers was also constructed.

Results

Tooth loss

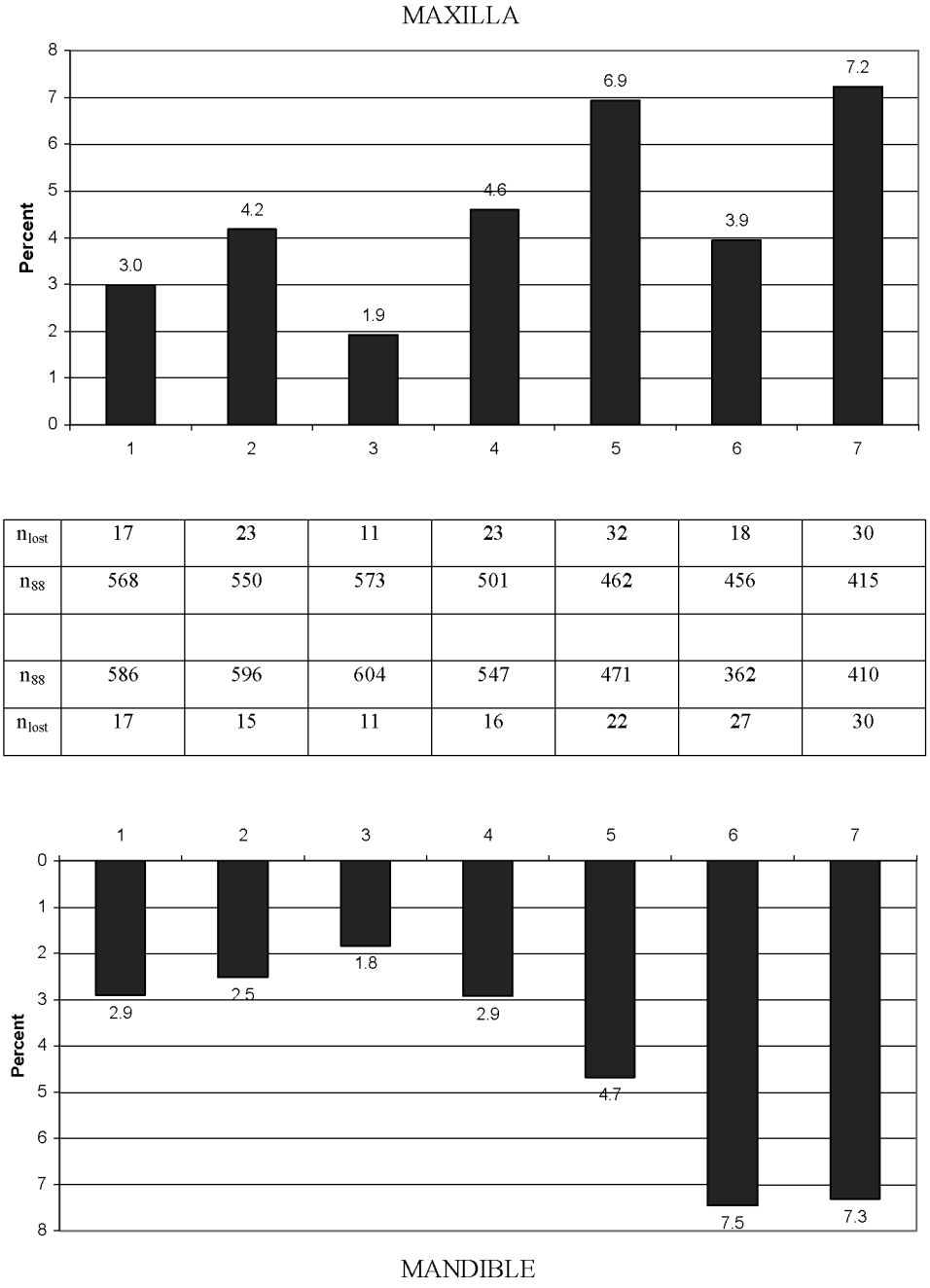
During the 10-year interval a total of 292 teeth (4.1%) out of the 7,101 present at baseline were lost in 122 (39%) of the 309 subjects. The incidence of tooth loss was greatest among mandibular molars (7.5%) and lowest among canines (1.8%) (Fig. 1). Maxillary 2nd premolars and maxillary and mandibular molars had a higher mortality rate than would have been expected according to the binomial proportion test. In this regard, the mortality rate for mandibular incisors and maxillary and mandibular canines was significantly lower ($P < 0.01$).

Teeth that had compromised *endodontic condition$_{88}$* (14.0%) had a relative risk (RR) of 4.1 (95% CI 3.23–5.19) of being lost. If only teeth with root canal retained posts (9.5%) were considered, the RR was 4.5 (95% CI 3.49–5.70). The RR for loss of molars with *furcation*

involvement$_{88}$ was 6.5 (95% CI 2.50–16.90) for 1st maxillary molars, 3.5 (95% CI 1.72–7.28) for 2nd maxillary molars, 3.9 (95% CI 1.83–8.23) for mandibular 1st molars, and 2.4 (95% CI 1.09–5.11) for 2nd mandibular molars.

For all tooth categories, smokers generally exhibited a higher tooth mortality rate than non-smokers. A significantly increased RR, however, was found only for the maxillary 1st incisor (2.1, 95% CI 1.29–3.31), the mandibular 2nd incisor (1.8, 95% CI 1.01–3.31), and the mandibular 2nd molar (RR 2.1, 95% CI 1.35–3.16).

The binary logistic regression model for tooth loss identified *ABL*$_{88}$, *endodontic condition*$_{88}$, probing pocket depth $\geq$4 mm (*CPITN score*$_{88}$ *3–4*), 'tooth position', 'educational level' and *caries*$_{88}$ as statistically significant factors



n_{lost}	17	23	11	23	32	18	30
n_{88}	568	550	573	501	462	456	415
n_{88}	586	596	604	547	471	362	410
n_{lost}	17	15	11	16	22	27	30

Fig. 1. Number of teeth 1988 (n_{88}), frequency of lost teeth 1988–1998 (n_{lost}), and percentage of lost teeth (bars) in relation to maxillary and mandibular contralateral tooth position.

Table 1. All individuals. Binary logistic backwards stepwise regression analysis ($n = 7{,}101$). Dependent variable: tooth loss

Independent variable	Coefficient	S.E.	OR	95% CI
Constant	−6.20	0.309		
Educational level (low)	0.47	0.141	1.60	1.22; 2.10
ABL_{88} (mm)	0.40	0.040	1.50	1.38; 1.62
Endodontic $condition_{88}$	1.36	0.145	3.88	2.92; 5.15
$Caries_{88}$ (yes)	0.75	0.285	2.13	1.22; 3.72
Jaw (maxilla)	0.27	0.141	1.31	0.99; 1.72
Central incisor (reference)				
Lateral incisor	0.26	0.280	1.30	0.75; 2.24
Canine	−0.26	0.332	0.77	0.40; 1.48
First premolar	0.58	0.279	1.79	1.03; 3.09
Second premolar	0.96	0.265	2.61	1.55; 4.39
First molar	0.70	0.277	2.02	1.17; 3.48
Second molar	1.16	0.268	3.18	1.88; 5.38
CPITN $score_{88}$ 0 (reference)				
CPITN $score_{88}$ 1	0.34	0.200	1.41	0.95; 2.09
CPITN $score_{88}$ 2	0.29	0.218	1.34	0.88; 2.06
CPITN $score_{88}$ 3	1.05	0.196	2.85	1.94; 4.18
CPITN $score_{88}$ 4	1.44	0.281	4.23	2.44; 7.34

ABL: Alveolar bone level. CPITN: Community Periodontal Index of Treatment Needs.

with odds ratios (OR) varying between 1.5 and 4.2 (Table 1). Teeth with ABL_{88} corresponding to a bone loss of 1/3 of the root length had an OR of 7.5 for being lost, whereas a probing pocket depth of ≥6 mm (*CPITN* $score_{88}$ *4*) rendered an OR of 4.2. 'Smoking habits' did not enter into the model as a significant risk factor for tooth loss.

Bone loss

A total of 5,256 teeth in 295 subjects were used for calculations of ABL change between 1988 and 1998 (77.2%). The overall mean 10-year ABL change calculated on the tooth level was −0.54 mm (S.E. 0.01; range −15.4 to +2.4 mm). In Fig. 2, the mean ABL_{88} and 10-year ABL change is presented for each tooth type. The mean ABL change ranged from −0.35 mm (mandibular 1st molars) to −0.79 mm (mandibular central incisor). The highest incidence of 'bone loss of >1 mm' was found for the mandibular central incisor (32%), while the incidence of 'bone loss of >2 mm' varied between 0% (1st maxillary premolar) and 8% (2nd mandibular incisor) for the various tooth types (Fig. 3).

Smokers had experienced a greater mean ABL change than non-smokers, with an increase varying from 20% to 131% depending on tooth type. In smokers, the mean ABL loss for the various tooth types was 0.42–1.02 mm, compared to 0.29–0.74 mm in non-smokers (Fig. 4).

In the binary forward logistic regression models for ABL change, maxillary and mandibular tooth positions were introduced separately because significant differences were found with respect to jaw. The variables that entered into the model (Table 2) were 'tooth type', 'smoking habits', ABL_{88} and probing pocket depth ≥4 mm (*CPITN* $score_{88}$ *3–4*). In comparison with the maxillary central incisor a significantly increased OR for bone loss was observed for mandibulary incisors (1.8–2.1). The OR for 'bone loss of >1' mm in smokers was 2.2 compared to non-smokers. For ABL_{88} a negative regression coefficient was found, i.e. the risk for further loss decreased (OR = 0.8) with each mm of increase in bone loss at baseline.

For the subgroup of non-smokers (Table 3), the same variables as identified in the total sample entered into the model. The regression coefficients and ORs were of similar magnitude as corresponding variables in the total sample, with the exception of *CPITN* $score_{88}$ *4,* i.e. probing pocket depth of ≥6 mm (OR: 8.0 in non-smokers versus OR: 3.7 in the total sample).

Discussion

The results of the present 10-year prospective study demonstrated that tooth loss was more common in the molar than in the anterior tooth regions, while bone loss was mainly randomly distributed in the dentition. The predominant risk factors with regard to tooth loss were ABL_{88}, probing pocket depth ≥6 mm (*CPITN* $score_{88}$ 4) and compromised 'endodontic $condition_{88}$', whereas with regard to further radiographic bone loss at the individual tooth, probing pocket depth ≥6 mm at baseline and smoking habits were the predominant risk factors.

Tooth loss

Tooth loss was observed to be most common in the posterior regions of the dentition (Fig. 1). Hence, about 7% of the molars were lost between 50 and 60 years of age, compared to 2–4% of the anterior teeth. The finding that molars were lost more often than other categories of teeth is in agreement with observations by for example Papapanou et al. (16), Norderyd & Hugosson (7), and Laurell et al. (18). Besides periodontal disease (31), caries (32–34) and endodontic problems (32, 35) may have contributed to the tooth mortality observed. Indeed, the logistic regression model for tooth loss (Table 1) revealed that decayed, endodontically as well as periodontally diseased teeth had a significantly increased mortality risk. Furthermore, as reported by Paulander et al. (26), individuals who lost teeth during the study period, compared to the rest of the sample, showed higher mean ABL_{88} (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, $P < 0.001$). Although a number of studies have indicated that periodontal disease is the cause of comparatively few tooth extractions (36–39), the findings in the current study showed that the presence of severe periodontal disease was a factor that may have influenced the dentist's/patient's decision to extract a tooth. This conclusion is further supported by the observation of an increased mortality rate for teeth with furcation involvement (relative risk 2.4–6.5). Similar results were presented by Klock & Haugejorden (40), who reported that

approximately 40% of tooth extractions in subjects 46 years and older were caused by periodontal disease, and Gilbert et al. (41), who, in a 2-year prospective study of subjects 45 years and older, found attachment level to be a strong predictive factor for tooth loss. It should be recognized, however, that the decision to extract a tooth due to advanced periodontal disease may also be influenced by the position of the tooth. This is illustrated in the present sample by the fact that although anterior teeth had a similar amount of bone loss as posterior teeth, tooth loss in the front tooth region was less conspicuous (Figs 1 and 2).

Smoking habits was not found to be a significant factor for tooth loss, neither in the binary logistic regression model nor in the bivariate tests. This observation is in agreement with results from a recent 20-year longitudinal cohort study by Jansson & Lavstedt (42), but is not consistent with data from a number of studies documenting smoking as a risk factor for periodontal disease (e.g. 13, 43, 44). Furthermore, low educational level predicted

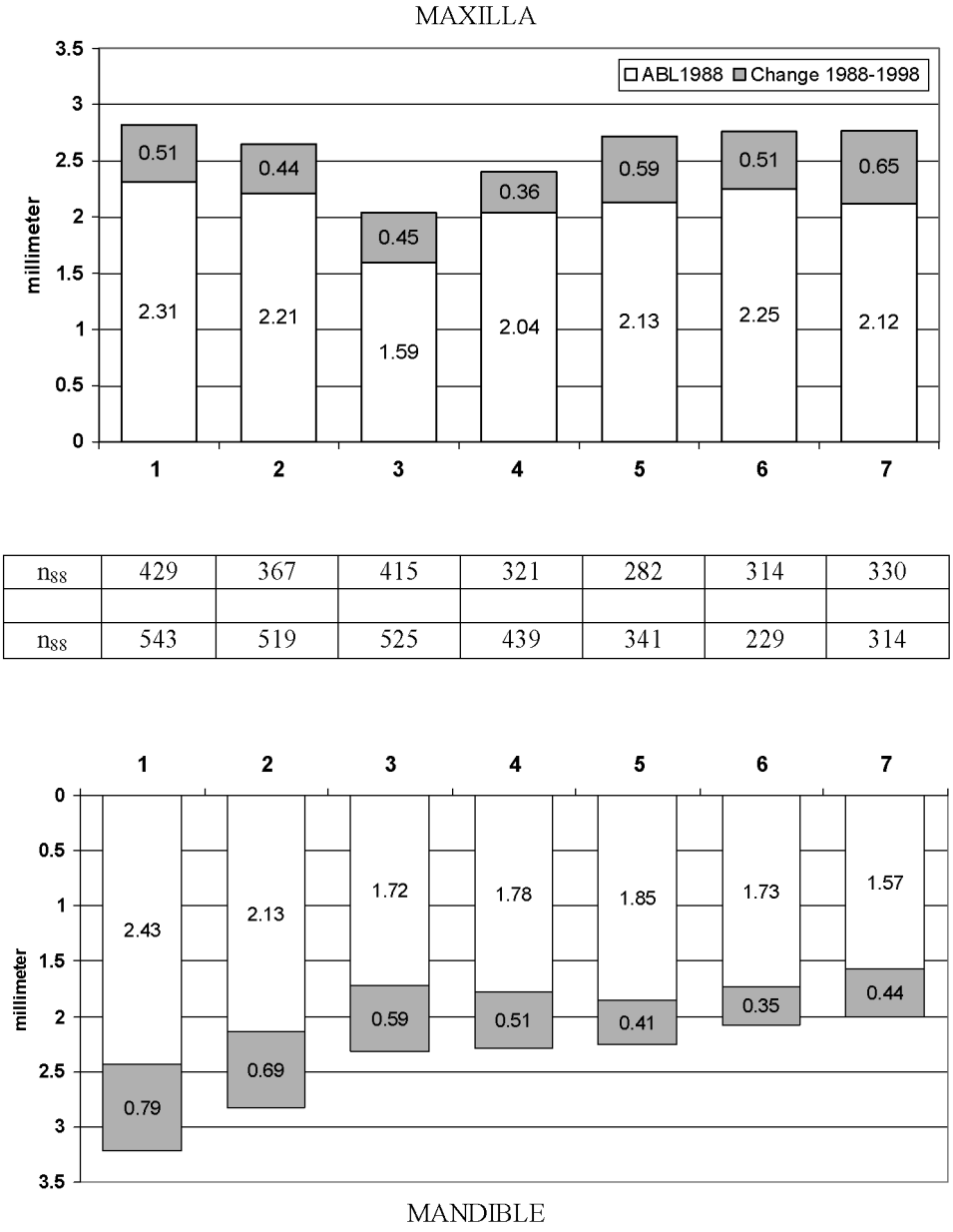


Fig. 2. Number of measured teeth (n_{88}), mean alveolar bone level (ABL) in 1988 and mean change of ABL 1988–1998 in relation to contralateral tooth position.

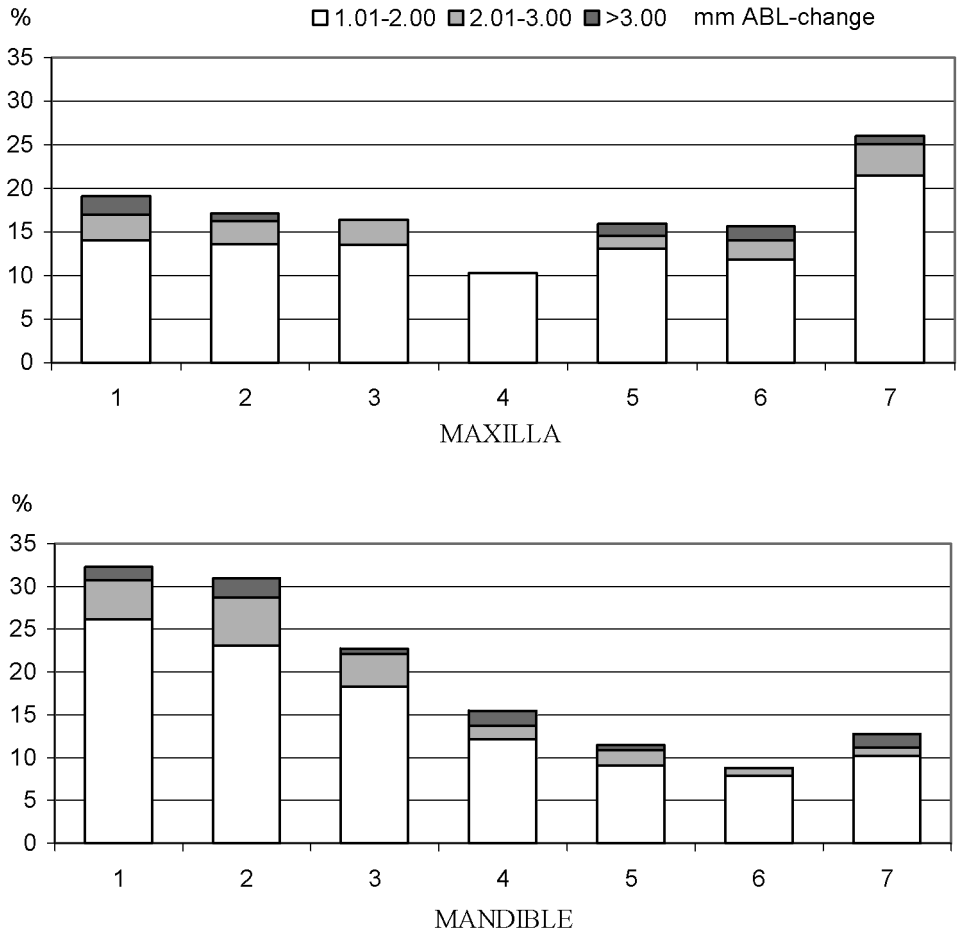


Fig. 3. Frequency of alveolar bone level loss >1 mm 1988–1998 in relation to tooth position.

tooth loss (OR = 1.6), which was in agreement with findings by Haugejorden et al. (45).

Bone loss

The incidence of progressive bone loss appeared to have a random distribution in the dentition (Fig. 2, Table 2) although a higher incidence of ABL change was found for mandibular incisors. This finding is in agreement with observations reported from other prospective studies (17, 18). In the study by Albandar (17), however, a slightly higher incidence of advanced bone loss was observed in maxillary molars, while in the study by Laurell et al. (18) a higher incidence of bone loss was reported for mandibular incisors and maxillary molars.

The ABL_{88} value and a probing pocket depth of $\geq$4 mm (*CPITN score$_{88}$ 3–4*) remained in the binary logistic regression model as significant factors for further bone loss. While increased probing pocket depth indicated an increased risk for disease progression, the initial degree of bone loss at a given tooth site was negatively correlated to additional bone loss. The latter finding that corroborates observations by others (16, 18, 46) may be explained by the fact that the more bone that has been lost at baseline, the higher was the risk for tooth loss during the course of the study. The validity of this proposal is supported by the outcome of the logistic regression analysis for tooth loss (Table 1), in which the ABL_{88} indicated a significantly increased risk (OR 1.5) for tooth loss.

A significant OR (2.2) for an ABL change of >1 mm was found for smokers in the logistic regression model (Table 2). In addition, smokers experienced a greater incidence of bone loss than non-smokers in all groups of teeth—the increase ranging from 20% to 131% (Fig. 4). These findings are in agreement with results reported from recent longitudinal investigations (18, 39, 42).

From the analysis based only on the subgroup of non-smokers (Table 3) it was observed that 'probing pocket depth of $\geq$6 mm' was an important risk factor for further bone loss (OR = 8.0). Furthermore, analysis of the entire sample as well as the subsample of non-smokers revealed

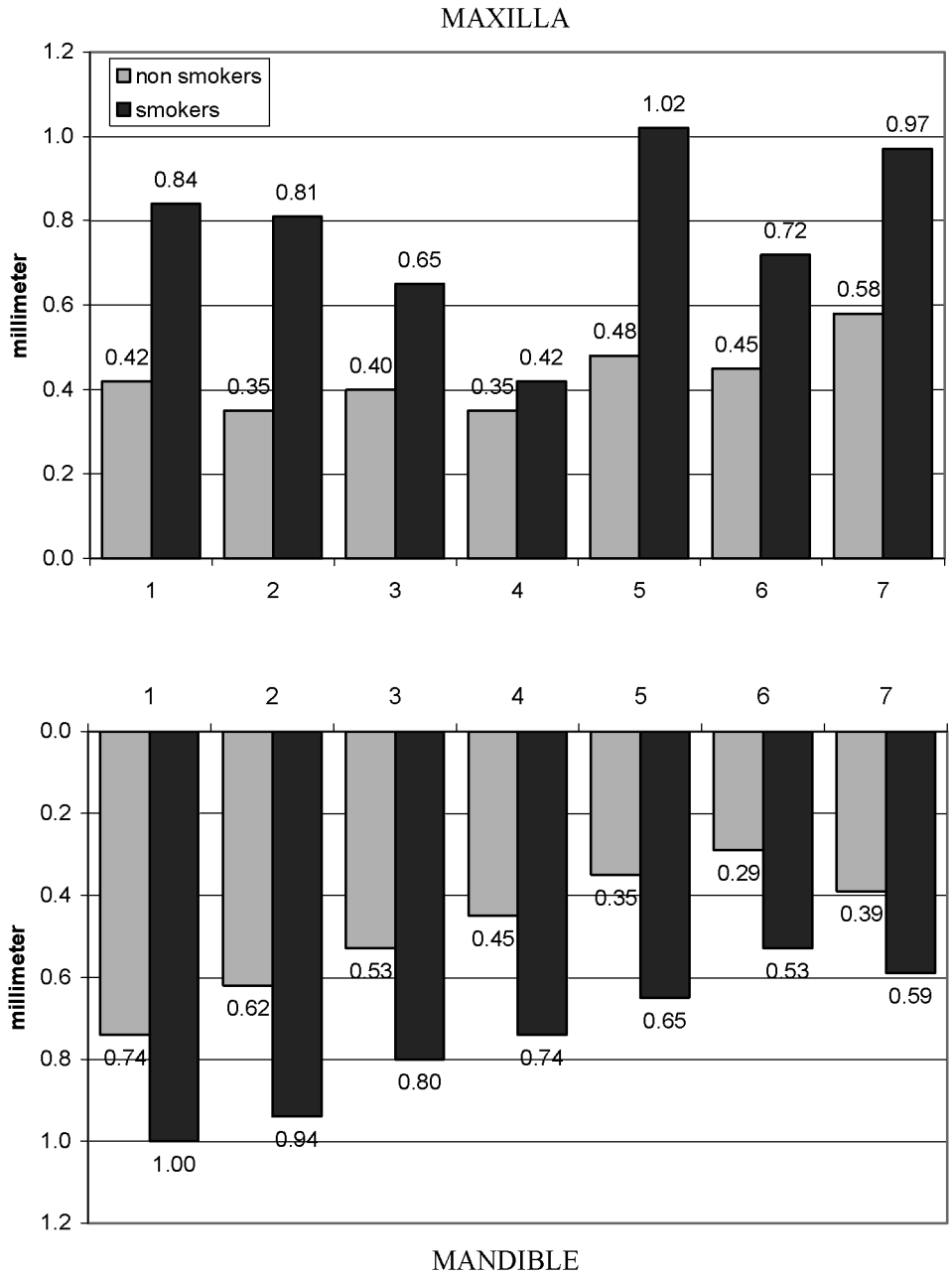


Fig. 4. Mean alveolar bone level loss 1988–1998 in non-smokers and smokers related to tooth position in the maxilla and mandible.

that 'probing pocket depth of ≥6 mm' was the strongest of all predictors that entered into the models for bone loss as well as tooth loss. These findings indicate that the relative impact of smoking on the progression of periodontal disease, and in turn on tooth loss, may be comparatively small compared with traditional descriptors of periodontal disease.

The results of the binary logistic model for bone loss in the subgroup of non-smokers (Table 3) were similar to those for the total sample. This finding differs from the observations made in corresponding analyses based on individual mean data for bone loss (26), in which only 'number of teeth' was a common factor that entered into the models. Hence, analysis of epidemiological data may lead to different outcomes depending on the observational entity (subject versus tooth) and the criterion used to define periodontal disease progression (a continuum versus cut-off values).

Table 2. All individuals. Binary logistic forward stepwise regression analysis ($n = 5,256$). Dependent variable: alveolar bone level loss >1 mm

Independent variable	Coefficient	S.E.	OR	95% CI
Constant	−1.09	0.148		
Smoker	0.79	0.083	2.21	1.88; 2.599
ABL_{88} (mm)	−0.27	0.036	0.76	0.71; 0.818
Maxilla 1 (reference)				
Maxilla 2	−0.13	0.191	0.88	0.61; 1.28
Maxilla 3	−0.38	0.187	0.69	0.48; 0.99
Maxilla 4	−0.85	0.228	0.43	0.27; 0.67
Maxilla 5	−0.28	0.210	0.75	0.50; 1.14
Maxilla 6	−0.41	0.207	0.66	0.44; 0.99
Maxilla 7	0.18	0.188	1.20	0.83; 1.73
Mandible 1	0.72	0.162	2.05	1.49; 2.82
Mandible 2	0.53	0.162	1.75	1.27; 2.41
Mandible 3	0.05	0.168	1.06	0.75; 1.46
Mandible 4	−0.36	0.186	0.70	0.48; 1.00
Mandible 5	−0.71	0.216	0.49	0.32; 0.75
Mandible 6	−1.10	0.271	0.33	0.20; 0.57
Mandible 7	−0.75	0.219	0.47	0.31; 0.73
CPITN $score_{88}$ 0 (reference)				
CPITN $score_{88}$ 1	0.05	0.099	1.05	0.87; 1.28
CPITN $score_{88}$ 2	0.19	0.104	1.21	0.99; 1.49
CPITN $score_{88}$ 3	0.67	0.148	1.96	1.47; 2.62
CPITN $score_{88}$ 4	1.31	0.341	3.72	1.91; 7.26

ABL: Alveolar bone level. CPITN: Community Periodontal Index of Treatment Needs.

Table 3. Non-smokers. Binary logistic forward stepwise regression analysis ($n = 4,024$). Dependent variable: alveolar bone level loss >1 mm

Independent variable	Coefficient	S.E.	OR	95% CI
Constant	−1.04	0.185		
ABL_{88} (mm)	−0.35	0.047	0.71	0.645; 0.78
Maxilla 1 (reference)				
Maxilla 2	−0.07	0.233	0.93	0.59; 1.47
Maxilla 3	−0.33	0.229	0.72	0.46; 1.12
Maxilla 4	−0.70	0.272	0.50	0.29; 0.85
Maxilla 5	−0.19	0.253	0.83	0.51; 1.36
Maxilla 6	−0.36	0.255	0.70	0.41; 1.16
Maxilla 7	0.17	0.228	1.19	0.76; 1.86
Mandible 1	0.85	0.197	2.33	1.58; 3.42
Mandible 2	0.64	0.198	1.89	1.28; 2.78
Mandible 3	0.08	0.207	1.08	0.72; 1.63
Mandible 4	−0.194	0.223	0.82	0.53; 1.28
Mandible 5	−0.75	0.271	0.47	0.28; 0.81
Mandible 6	−1.12	0.341	0.33	0.17; 0.64
Mandible 7	−0.80	0.272	0.43	0.26; 0.76
CPITN $score_{88}$ 0 (reference)				
CPITN $score_{88}$ 1	0.08	0.113	1.08	0.85; 1.33
CPITN $score_{88}$ 2	0.20	0.123	1.22	0.96; 1.55
CPITN $score_{88}$ 3	0.65	0.197	1.91	1.27; 2.76
CPITN $score_{88}$ 4	2.08	0.498	8.03	3.05; 21.49

ABL: Alveolar bone level. CPITN: Community Periodontal Index of Treatment Needs.

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