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ORIGINAL ARTICLE

Risk factors and risk indicators in relation to incipient alveolar bone loss in Swedish 19-year-olds

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Abstract

Objective. To investigate incipient alveolar bone loss and subgingival calculus on a subject-based level in Swedish 19-year-olds, with special reference to risk factors and risk indicators. ***Material and methods.*** Subjects ($n = 686$) with different socio-economic profiles enrolled at seven public dental clinics in suburban Stockholm answered a questionnaire on general health, tobacco habits, oral hygiene habits, and their parents' socio-economic background. The clinical and radiographic examination included registration of plaque, bleeding on probing (GBI), supra- and subgingival calculus, caries, and restorations. Incipient alveolar bone loss was recorded when the distance from the cemento-enamel junction to the alveolar crest was ≥ 2.0 mm. ***Results.*** The prevalence of incipient alveolar bone loss was 5.1%; multivariate analysis disclosed the associated variables to be "subgingival calculus" (odds ratio (OR) 4.2) and "proximal restoration ≥ 1" (OR 2.1). The cumulative probability of exhibiting incipient alveolar bone loss was 19.6%. The prevalence of subgingival calculus was 14.3% and subgingival calculus was associated with "GBI $> 25\%$" (OR 6.0), "supragingival calculus" (OR 4.6), and "father born abroad" (OR 2.8). The cumulative probability of exhibiting subgingival calculus was estimated to be 65.3%. ***Conclusions.*** Adolescents with subgingival calculus as well as proximal restorations are at higher relative risk of exhibiting incipient alveolar bone loss than are those without subgingival calculus. In contrast to incipient alveolar bone loss, immigrant background was significantly associated with subgingival calculus among Swedish adolescents.

Key Words: *Calculus, dental caries, ethnicity, periodontitis, teenager*

Introduction

Periodontitis is classified as chronic, aggressive, or as a manifestation of, systemic disease [1]. With respect to chronic periodontitis in adolescents, there are pronounced variations in the reported prevalence between different populations [2]. In addition, the disparity of prevalence is due to the different methods [3,4] and criteria used [5,6]. In Scandinavian studies of radiographic alveolar bone loss in 18 to 20-year-olds, the reported prevalence is around 1–4% [5,7,8]. In most studies, alveolar bone loss is recorded as present when distance from the cemento-enamel junction (CEJ) to the alveolar crest (AC) on radiographs exceeds 2.0 mm [4,9]. While there is a lack of consensus as to what constitutes alveolar bone loss on a radiograph, Hausmann et al. [10] concluded that no alveolar bone loss was consistent with a range of radiographic CEJ-AC distances < 2.0 mm.

The risk of periodontitis is defined as the probability that the disease will occur in the future, or the probability that an individual will develop the disease or experience a deterioration in periodontal health during a specified interval of time [11,12]. Risk factors reported in longitudinal studies to be associated with chronic periodontitis in adolescents and young adults include the presence of subgingival calculus [13,14], dental caries or restorations [15,16], smoking habit [17], and the presence of periodontal pathogens, e.g. *Aggregatibacter actinomycetemcomitans*, former *Actinobacillus actinomycetemcomitans (A.a)* [8,14,18,19], *Porphyromonas gingivalis* [20], *Tanerella forsythensis* [21], *Prevotella intermedia* [20], and *Treponema denticola* [20].

Risk indicators reported to be associated with chronic periodontitis in adolescents and young adults include gender (males) [12,14], race/ethnicity [7,22], and parental socio-economic status assessed by educational level [23] and income [23].

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The primary aim of the present study, on a subject-based level, was to investigate risk factors and risk indicators associated with the occurrence of incipient alveolar bone loss in Swedish 19-year-olds, with special reference to immigrant background. A secondary aim was to determine the occurrence of risk indicators and risk factors in relation to subgingival calculus.

Material and methods

The study design was cross-sectional and was approved by the local ethics committee at Karolinska Institutet, Huddinge University Hospital. The study population comprised 19-year-olds with different socio-economic profiles enrolled in the public dental service at seven clinics in the County of Stockholm. A letter of information about the purpose of the investigation was enclosed with the annual recall notices sent to the subjects between 1 March and 30 November 2001. Out of 800 consecutive but randomly selected subjects, described previously [24], in which risk determinants were analysed in relation to high caries experience, 696 (87%) attended the examination appointment (364 M and 332 F). In 10 subjects, data on periodontal variables were missing and they were therefore excluded. Of the final study group ($n=686$), 197 lived in suburbs with a high socio-economic profile, 189 in suburbs with a medium socio-economic profile, and 300 in suburbs with a low socio-economic profile.

A power analysis was performed before the start of the study to detect a difference in the prevalence of incipient alveolar bone loss between subjects with and those without foreign-born parents. The following assumptions were made based on previous data [7]: 5% significance level and 80% power; required a sample size of 191 subjects. To perform the power analysis we used the computer program nQuery Advisor: two group chi-square test of equal proportions with unequal n's.

Questionnaire

The subjects answered a structured questionnaire and an interpreter assisted those who did not understand the Swedish language. The questionnaire covered such topics as socio-economic status and country of birth of the subjects' parents, and, with respect to the subjects themselves, general health, medication, tobacco habits, and oral hygiene habits. Socio-economic status was described in terms of the parents' educational level and occupational status. Educational level was stratified in accordance with years of schooling as: 1) low (≤ 9 years), 2) medium (10–12 years), and 3) high (>12 years). Occupational status was assessed in accordance with the Swedish socio-economic classification [25]: 1) unemployed, 2) manual workers, and 3) semi-skilled and skilled white-collar workers. When mother and father were combined in one group, the socio-economic status of the family was determined by the lower educational level or by the occupational status of the mother.

Country of birth of the parents was coded on a geographic basis: born in Sweden, born in Europe, born elsewhere. In the bi- and multivariate analyses, the categories "born in Europe" and "born elsewhere" were combined within one group, "born abroad". An individual was defined as having parents born abroad if at least one of the parents was born outside Sweden.

Tobacco habits of the subjects were described in terms of cigarette smoking and snuff use. The frequency was expressed on a three-point scale: never, sometimes, or daily. In the statistical analysis, the categories "never" and "sometimes" were combined, for both cigarette smoking and snuff use, respectively, and referred to as "no daily".

Oral hygiene habits were described in terms of morning and evening toothbrushing, and use of dental floss. The frequency of each habit was expressed on a five-point scale: never, seldom, sometimes, often, or daily. In the statistical analysis, the categories of toothbrushing habits "never", "seldom", "sometimes", and "often" were combined and referred to as "irregular" toothbrushing. The variable "dental floss" formed two groups: "never", "seldom", "sometimes" were referred to as "seldom" and "often" and "daily" as "often".

Self-perceived gingival bleeding was expressed on a five-point scale: never, seldom, sometimes, often, or daily. In the statistical analysis, two groups were formed: "never", "seldom", and "sometimes" were combined and referred to as "seldom", and "often" and "daily" as "often".

Clinical and radiographic examination

Two or three dentists at each of the public dental clinics ($n=7$) conducted the clinical examination of the subjects. Prior to the study, all the examiners ($n=17$) were invited to attend a day-long course of training in registration of dental caries, plaque, and periodontal conditions according to specific diagnostic criteria and interpretation of responses to the questionnaire. Moreover, the examiners were calibrated with respect to registration of dental caries, visible dental plaque (VPI), and gingival inflammation (GBI). Inter-examiner reproducibility for dental plaque was 80%, with a mean kappa of 0.66, gingival bleeding 80% with a mean kappa of 0.61 [26]. Dental caries in the study group has been reported previously [24].

With respect to radiographic examination, three of the clinics used digital imaging systems and four clinics conventional dental films. The diagnostic accuracy for digital systems and conventional dental

films is comparable for detecting dental caries and alveolar bone loss [27,28]. In this study, a Dixi2 CCD sensor (Planmeca Oy, Helsinki, Finland) was used. Conventional radiographs, two bitewings, were taken by the standard technique.

Dental plaque. The presence of dental plaque was recorded when clearly visible on all tooth surfaces, except 3rd molars, and expressed as Visible Plaque Index (VPI) [29]. The proportion of surfaces with dental plaque was roughly estimated for each individual and expressed as VPI (%).

Gingival inflammation. Gingival inflammation was based on bleeding on probing the gingival sulcus of the 1st molars and central incisors and expressed as the Gingival Bleeding Index (GBI) [29]. The proportion of surfaces (%) with gingival inflammation was roughly estimated for each individual.

Supragingival calculus. Supragingival calculus was recorded as present or absent when clearly visible in the upper and lower jaw.

Subgingival calculus. Clinically detected subgingival calculus was recorded as present or absent after probing the gingival sulcus of 1st molars and central incisors with a manual graded periodontal probe (LM-instruments OY, Finland). Radiographically detected subgingival calculus was recorded as present or absent on the proximal surfaces of premolars and molars. In the statistical analysis, the variable "subgingival calculus" was based on radiographically detected subgingival calculus as well as on clinically diagnosed subgingival calculus.

Incipient alveolar bone loss. The mesial and distal surfaces of all 1st permanent molars on radiographs were analysed ($n = 5488$ sites). The readable sites were 93% and, of these, 2408 sites were read from digital radiographs and 2696 from conventional radiographs. The distance between CEJ and AC was determined on conventional radiographs using a Peak scale loupe (Carton Optic, Tokyo, Japan; 7-fold magnification). The loupe is provided with a scale permitting measurement to the nearest 0.1 mm. The distance from the CEJ to AC on digital radiographs was determined using the software program Dimaxis (Planmeca Oy, Helsinki, Finland). All measurements were carried out by two of the authors (A.J. and M.B.A.). Incipient alveolar bone loss was recorded when the distance between CEJ and AC was 2.0 mm or more at one or more sites. An inter-examiner test was conducted. Full agreement in classification of sites with CEJ-AC ($\geq$2.0 mm) or CEJ-AC ($<$2.0 mm) was 89% with a mean kappa [26] of 0.63.

Dental caries. The numbers of decayed (D), missing (M), and filled (F) teeth (T)/surfaces (S) were registered and expressed as DMFT/S indices.

Dental restorations. The occurrence of proximal filled surfaces (FSa $\geq$1) was registered as composite fillings or amalgam fillings.

Statistics

Data analysis was carried out using the statistical software package SPSS, version 13.0. Cross tables and logistic regression were used for analysing the data and frequency tables. All clinical variables were dichotomized to be included in the statistical model (multivariate logistic regression). To check the impact of participating public dental clinics, the clinic as variable was included in the model. Bivariate analyses of associations were carried out between the dependent variables, "incipient alveolar bone loss" and "subgingival calculus", and the potential independent variables by applying Pearson's chi-square test in cross tables and by logistic regression binary model. Inter-correlations between the covariates in Table III were also tested. The unit in the statistical analyses was subject-based and the dependent variables were dichotomized concerning occurrence.

Multivariate logistic regression was used to calculate adjusted OR and 95% confidence intervals (95% CI) [30]. The multivariate analyses were carried out in a forward stepwise manner. All covariates in the bivariate analyses (Table III) competed in the multivariate analyses. In the bivariate as well as multivariate analyses, adjustment was made for both parents' educational level as well as occupational status. Logistic regression analyses were also used to calculate the cumulative probability (%) of incipient alveolar bone loss and of presence of subgingival calculus [31].

Results

The characteristics of the subjects with respect to gender, general health, tobacco habits, country of birth, and years of living in Sweden, as well as their parents' country of birth, educational level, and occupational status, are given in Table I.

Periodontal variables and caries indices of the subjects are presented in Table II. Of the subjects, 14.3% exhibited subgingival calculus and 5.1% incipient alveolar bone loss.

Table I. Characteristics of the subjects ($n=686$).

Variables	n	%
Subjects		
Gender		
Male	358	52
Female	328	48
General health		
Chronic disease	31	5
Allergy	180	26
Regular medication	121	18
Tobacco habits		
Smoking, daily	135	20
Snuff use, daily	80	12
Country of birth		
Born in Sweden	558	81
Born abroad	128	19
Years living in Sweden		
<10 years	41	6
≥10 years	645	94
Parents		
Country of birth		
Born in Sweden	348	50
Born abroad	338	49
Educational level		
Low		
Born in Sweden	54	8
Born abroad	160	23
Medium		
Born in Sweden	128	19
Born abroad	95	14
High		
Born in Sweden	152	22
Born abroad	77	11
No information	20	3
Occupational status		
Unemployed		
Born in Sweden	28	4
Born abroad	106	15
Manual workers		
Born in Sweden	102	15
Born abroad	130	19
White collar workers		
Born in Sweden	191	28
Born abroad	65	10
No information	64	9

Table II. Clinical variables and oral hygiene variables in 19-year-old adolescents ($n=686$).

Variables	%
Clinical variables	
VPI	
≤25%	89
>25%	11
GBI	
≤25%	88
>25%	12
Self-perceived gingival bleeding	
Seldom	63
Often	37
Supragingival calculus	
No	45
Yes	55
Subgingival calculus	
No	86
Yes	14
Incipient alveolar bone loss	
CEJ-AC ≥2.0 mm	
No	95
Yes	5
Caries indices	
DMFT ≥1	81
DMFS ≥1	81
DMFSa ≥1	43
DSa ≥1	23
FSa ≥1	35
Oral hygiene variables	
Toothbrushing in the morning	
Never	1
Daily	75
Irregular	24
Toothbrushing at night	
Never	1
Nightly	71
Irregular	28
Use of dental floss	
Seldom	38
Often	62

D = decayed, M = missed, F = filled, T = teeth, S = surface, a = proximal.

Adolescents with/without incipient alveolar bone loss

Adolescents with or without incipient alveolar bone loss were compared with respect to clinic, their parents' educational level, occupational status, and country of birth, as well as with their own country of birth, years of living in Sweden, occurrence of chronic disease, medication, tobacco habits, oral hygiene habits, dental caries, and periodontal variables. After adjustment for education and occupation in the bivariate analysis, the following variables were significantly associated with incipient alveolar bone loss: "clinic" ($p=0.016$), "self-perceived gingival bleeding" ($p=0.043$), "subgingival calculus" ($p=0.001$), and "FSa ≥1" ($p=0.034$), "mother born abroad" ($p=0.039$), and "father born abroad" ($p=0.031$) (Table III).

All covariates in the bivariate analysis (Table III) competed in a multivariate logistic regression analysis, with incipient alveolar bone loss as the dependent variable. The OR and the 95% CI were determined for each variable (Table IV). On a subject-based level, the variables associated with incipient alveolar bone loss were "subgingival calculus" ($p<0.001$) and "FSa ≥1" ($p=0.05$). The OR was 4.2 for the variable "subgingival calculus" and 2.1 for "FSa ≥1".

The logistic regression analysis was also used to estimate the probability of incipient alveolar bone loss for the given profile of independent variables. In the absence of all the significant variables, the

Table III. Adolescents with or without incipient alveolar bone loss at one or more sites ($n=686$).

Variables	Incipient alveolar bone loss: No ($n=651$) %	Yes ($n=35$) %	Crude OR[a]; 95% CI	p-value[b]	Adjusted OR[a]; 95% CI	p-value[b]
Dental clinics						
Low socio-economic profile				0.014		0.016
Clinic 1	14	14	1.00		1.00	
Clinic 2	13	34	2.46; 0.83–7.27	0.105	2.10; 0.69–6.37	0.191
Clinic 3	16	11	0.67; 0.18–2.57	0.560	0.45; 0.10–1.94	0.283
Medium socio-economic profile						
Clinic 4	14	6	0.38; 0.07–2.00	0.253	0.29; 0.05–1.59	0.153
Clinic 5	13	23	1.70; 0.53–5.40	0.371	1.10; 0.32–3.80	0.885
High socio-economic profile						
Clinic 6	17	6	0.42; 0.08–2.22	0.306	0.29; 0.05–1.62	0.159
Clinic 7	13	6	0.31; 0.06–1.66	0.173	0.20; 0.04–1.17	0.074
Subjects						
Gender						
Male	52	58	1.00		1.00	
Female	48	42	0.63; 0.31–1.27	0.198	0.52; 0.25–1.09	0.083
General health						
Chronic disease						
No	95	100	1.00		1.00	
Yes	5	0	0.00; 0.00–0.00	0.998	0.00; 0.00–0.00	0.998
Allergy						
No	73	80	1.00		1.00	
Yes	27	20	0.69; 0.29–1.60	0.384	0.63; 0.25–1.55	0.311
Regular medication						
No	82	94	1.00		1.00	
Yes	18	6	0.27; 0.06–1.13	0.074	0.28; 0.07–1.19	0.085
Tobacco habits						
Smoking, daily						
No	81	71	1.00		1.00	
Yes	19	29	1.33; 0.90–1.97	0.158	1.22; 0.80–1.86	0.369
Snuff use, daily						
No	88	86	1.00		1.00	
Yes	12	14	1.08; 0.66–1.77	0.747	1.15; 0.70–1.89	0.590
Clinical variables						
VPI						
≤25%	89	89	1.00		1.00	
>25%	11	11	1.02; 0.35–2.98	0.969	1.06; 0.36–3.14	0.914
Self-perceived gingival bleeding						
Seldom	64	46	1.00		1.00	
Often	36	54	2.07; 1.05–4.11	0.037	2.08; 1.02–4.23	0.043
GBI						
≤25%	88	86	1.00		1.00	
>25%	12	14	1.24; 0.47–3.30	0.663	0.75; 0.22–2.57	0.649
Supragingival calculus						
No	45	49	1.00		1.00	
Yes	55	51	0.86;0.43–1.69	0.654	0.74;0.36–1.50	0.398
Subgingival calculus						
No	87	60	1.00		1.00	
Yes	13	40	4.44; 2.18–9.06	<0.001	3.74; 1.74–8.05	0.001
FSa ≥1						
No	66	46	1.00		1.00	
Yes	34	54	2.26; 1.14–4.49	0.019	2.16; 1.06–4.42	0.034
DSa ≥1						
No	78	71	1.00		1.00	
Yes	22	29	1.38; 0.65–2.95	0.400	1.54; 0.71–3.35	0.271

Table III (*Continued*)

Variables	Incipient alveolar bone loss: No ($n=651$) %	Yes ($n=35$) %	Crude OR[a]; 95% CI	p-value[b]	Adjusted OR[a]; 95% CI	p-value[b]
Oral hygiene variables						
Toothbrushing in the morning						
Daily	76	77	1.00		1.00	
Irregular	24	23	1.06; 0.47–2.39	0.881	1.04; 0.46–2.37	0.920
Toothbrushing at night						
Nightly	72	66	1.00		1.00	
Irregular	28	34	0.73; 0.35–1.49	0.384	0.84; 0.38–1.85	0.664
Use of dental floss						
Seldom	38	37	1.00		1.00	
Often	62	63	1.05; 0.52–2.13	0.885	1.14; 0.55–2.38	0.723
Parents						
Country of birth						
Mother						
Born in Sweden	56	34	1.00		1.00	
Born abroad	44	66	2.45; 1.20–5.02	0.014	2.35; 1.04–5.29	0.039
Father						
Born in Sweden	59	40	1.00		1.00	
Born abroad	41	60	2.18; 1.09–4.36	0.028	2.60; 1.13–5.97	0.031
Educational level						
Mother				0.397		0.316
≤9 years	32	37	1.00		1.00	
10–12 years	34	23	0.58; 0.24–1.43	0.234	0.53; 0.19–1.45	0.215
>12 years	34	40	1.02; 0.47–2.23	0.956	1.05; 0.38–2.89	0.923
Father				0.790		0.807
≤9 years	32	37	1.00		1.00	
10–12 years	32	32	0.86; 0.37–1.95	0.709	0.93; 0.39–2.20	0.861
>12 years	36	31	0.75; 0.33–1.71	0.494	0.73; 0.28–1.93	0.525
Occupational status						
Mother				0.674		0.729
Unemployed	20	26	1.00		1.00	
Manual laborers	27	23	1.12; 0.48–2.62	0.802	0.96; 0.35–2.63	0.939
White-collar workers	53	51	1.52; 0.57–4.04	0.406	1.41; 0.52–3.82	0.501
Father				0.187		0.135
Unemployed	14	23	1.00		1.00	
Manual laborers	36	43	0.59; 0.27–1.29	0.188	0.51; 0.22–1.16	0.108
White-collar workers	50	34	1.35; 0.55–3.28	0.515	1.36; 0.55–3.38	0.510

[a]Odds ratios of reference categories have been set to 1.00.
[b]*P*-values refer to binary logistic regression analyses.
Adjusted for education level and occupation status for both mother and father.
Incipient alveolar bone loss = CEJ-AC ≥2.0 mm.

estimated probability of incipient alveolar bone loss in adolescents was 2.6%. When subgingival calculus was present, the probability increased to 10.3%, and when both subgingival calculus and proximal restorations were present it increased to 19.6%.

Adolescents with/without subgingival calculus

Adolescents with or without occurrence of subgingival calculus were compared with respect to clinic, their parents' educational level, occupational status, and country of birth as well as with their own country of birth, years of living in Sweden, occurrence of chronic disease, medication, tobacco habits, oral hygiene habits, dental caries, and periodontal variables. After adjustment for education and occupation, the following variables in the bivariate analysis were significantly associated with subgingival calculus: "clinic" ($p<0.001$), "mother born abroad" ($p<0.001$), "father born abroad" ($p<0.001$), "mother's educational level" ($p=0.018$), "mother's occupational status" ($p=0.019$), and "father's occupational status" ($p=0.011$) as well as the adolescents' "irregular toothbrushing at night" ($p=0.013$), "self-perceived gingival bleeding" ($p=0.050$), "VPI >25%" ($p<0.001$), "GBI >25%" ($p<0.001$), "supragingival calculus" ($p<0.001$), and "proximal decayed surface ≥1 (DSa ≥1)" ($p=0.017$).

Table IV. Multivariate logistic regression analysis with incipient alveolar bone loss, at one or more sites, as the dependent variable ($n = 686$).

Variables	Beta coefficient ß	OR	95% CI
Subgingival calculus	1.4	4.2	2.1–8.7
FSa ≥ 1	0.8	2.1	1.1–4.3

ß = regression coefficient; OR = odds ratio; CI = confidence interval.
Incipient alveolar bone loss = CEJ-AC ≥ 2.0 mm.
Adjusted for education level and occupation status for both mother and father.

All covariates in the bivariate analyses competed in a multivariate logistic regression analysis with subgingival calculus as the dependent variable. The OR and the 95% CI were determined for each variable (Table V). On a subject-based level, the variables most strongly associated with the occurrence of subgingival calculus were "GBI > 25%" ($p < 0.001$), "supragingival calculus" ($p < 0.001$), and "father born abroad" ($p < 0.001$). For "GBI > 25%" the OR was 6.0; for "supragingival calculus", 4.6; and for the variable "father born abroad", 2.8.

The logistic regression analysis was also used to calculate the cumulative probability (%) of subgingival calculus. In the absence of all the significant variables, the estimated probability of subgingival calculus in adolescents was 2.0%. When all significant variables were present, the cumulative probability was 65.3%.

Inter-correlation

Inter-correlation between the covariates of the bivariate analysis was tested. The strongest collinearity was found between the variables "mother born abroad" and "father born abroad" ($r^2 = 0.54$). The following variables exhibited a r^2 value within the interval 0.5 to 0.1; "VPI > 25%" and "GBI > 25%" ($r^2 = 0.48$), "mothers' educational level" and "fathers' educational level" ($r^2 = 0.24$), "mothers' educational level" and "father born abroad" ($r^2 = 0.14$), "subgingival calculus" and "GBI > 25%" ($r^2 = 0.12$), "FSa ≥ 1" and "DSa ≥ 1" ($r^2 = 0.12$), "mothers' educational level" and "mother born abroad" ($r^2 = 0.11$).

Table V. Multivariate logistic regression analysis with subgingival calculus as the dependent variable ($n = 686$).

Variables	Beta coefficient ß	OR	95% CI
GBI > 25%	1.80	6.0	3.48–10.48
Supragingival calculus	1.54	4.6	2.55–8.46
Father born abroad	1.02	2.8	1.70–4.57

ß = regression coefficient; OR = odds ratio; CI = confidence interval.
Adjusted for education level and occupation status for both mother and father.

Discussion

The present cross-sectional study demonstrates that there was no association between immigrant background and incipient alveolar bone loss among Swedish adolescents. On the subject-based level, the variables associated with incipient alveolar bone loss were subgingival calculus and proximal restorations. When these two independent variables were present, the cumulative probability of incipient alveolar bone loss was estimated to be 19.6%. Furthermore, the variables associated with subgingival calculus were gingival bleeding, supragingival calculus, and foreign-born father. When all independent variables were present, the final cumulative probability of subgingival calculus was 65.3%.

The subjects were residents of different suburbs of Stockholm. The power analysis concerning caries, previously reported [24], showed that 400 subjects with foreign-born parents were needed; a majority were recruited from suburbs with low socio-economic profile. To evaluate for any specific clinic effect, clinic as variable was included in the logistic regression analysis. Although the bivariate analysis showed a significant difference between the clinics, the variable "clinic" was not significant in the multivariate analysis. This was found for both "incipient alveolar bone loss" and "subgingival calculus".

The inter-examiner test for recording dental plaque, gingival bleeding, and incipient alveolar bone loss demonstrated good agreement [32], indicating that these data may be reliably recorded even when several examiners are involved. Measurements of periodontal pocket depth, however, were not included in the clinical examination because of insufficient validity in the registration [33].

Chronic periodontitis was not used as outcome owing to a lack of uniform criteria for chronic periodontitis in adolescents [34] and the fact that periodontal outcome was based exclusively on radiographs [35]. Moreover, the study design was cross-sectional, which precludes the possibility to determine the progression and severity of the disease as well. Due to low age of the subjects, the cut-off level regarding the distance from the CEJ to AC on the radiographs was ≥ 2.0 mm, when incipient alveolar bone loss was classified [34]. However, one has to consider that there is lack of consensus as to what constitutes alveolar bone loss in adolescents [9,10]. The frequency of incipient alveolar bone loss among our subjects (5.1%) was in the same order of magnitude as in previous studies on 19-year-olds in Scandinavia [7,8], although these classified radiographic alveolar bone loss when the distance CEJ-AC of permanent molars exceeded 2.0 mm.

The variables in this study were mainly subject-based, and all clinical data were dichotomized and

analyzed on an individual level. Site-based analyses with dependency between observational variables were excluded because of an enhanced risk of over-representation of the perception of disease [36]. Among the risk factors and risk indicators analyzed, multivariate analysis disclosed only subgingival calculus and proximal restoration as significant variables associated with the occurrence of incipient alveolar bone loss. When these two independent variables were present, the cumulative probability of incipient alveolar bone loss was 19.6%. It is not possible to evaluate whether this figure of probability is low or high, since no data are available regarding the magnitude of cumulative probability of these independent variables.

In the multivariate analysis with incipient alveolar bone loss as dependent variable, the OR for subgingival calculus was estimated as 4.2, which is considerably higher compared with that of Timmerman et al. [18] and of Van der Velden et al. [14]. Those authors reported the OR of subgingival calculus as a risk factor for the onset of clinical attachment loss in young adults to be 1.2 and 1.4, respectively.

We also demonstrated that adolescents with proximal dental restorations exhibited a 2-fold higher estimated probability of exhibiting incipient alveolar bone loss. In the analysis, composite restorations were not separated from amalgam restorations due to the fact that amalgam is not normally used as filling material in children in Sweden. On a site-based level, Albandar et al. [15] and Broadbent et al. [16] concluded that proximal restoration was a risk factor for periodontal breakdown. In contrast to Albandar et al. [15], we did not disclose any significant association between proximal caries and incipient alveolar bone loss.

In the present study, the multivariate analysis failed to demonstrate any association between immigrant background and incipient alveolar bone loss, although such a relationship was evident in the bivariate analysis. There is evidence in the literature that a higher risk of young adults developing chronic periodontitis is associated with certain race/ethnicity groups [22]. American studies have found higher prevalences of chronic periodontitis in blacks and in Hispanics compared to white adolescents and young adults of similar age [22]. Similarly, Dahllöf et al. [7] showed a significant higher prevalence of radiographic alveolar bone loss in adolescents with foreign-born parents compared to adolescents with Swedish-born parents. The lack of association between immigrant background and incipient alveolar bone loss in our study might to some extent be due to the limited number of subjects with incipient alveolar bone loss. Immigrant background, however, may indirectly influence attitudes to dental care and/or oral hygiene [37], thereby affecting periodontal health. This view is compatible with our results that adolescents of foreign-born fathers exhibit 2.5 times higher estimated probability for subgingival calculus than those whose fathers are Swedish-born. This relationship between immigrant background and subgingival calculus in adolescents has been reported previously [7].

Although smoking is well documented as a risk factor in chronic periodontitis [12], neither bivariate nor multivariate analysis disclosed any significant association between smoking and incipient alveolar bone loss. This concurs with a study on Chilean teenagers [3], but contrasts with studies by Machuca et al. and Hashim et al. [17,38]. The frequency of daily smokers in our subjects (20%) is in the same order of magnitude as found by Lopez et al. [3] (24.5%), but considerably lower compared to findings by Machuca et al. [17] and Hashim et al. [38], who reported a much higher frequency (53–76%). In our study, no information was available among the subjects regarding number of cigarettes smoked per day or duration of smoking habit. The lack of an association between smoking and incipient alveolar bone loss in our study is probably attributable to the fact that there were few daily smokers. This assumption is based on the fact that the power of the variable "smoking habit" was only 40%, based on a post-hoc power analysis. Another explanation could be that the daily smokers in this study were not as heavy or habitual as smokers in other studies, in which a close relationship between smoking and alveolar bone loss was demonstrated [17,38].

In the collinearity analysis, the r^2 value of all inter-correlations between covariates was <0.55; the risk for strong collinearity occurs when the r^2 value is >0.8. The low inter-correlations indicate that the results of the multivariate analysis are valid.

In conclusion, adolescents with subgingival calculus as well as proximal restorations are at higher relative risk of exhibiting incipient alveolar bone loss compared to those without. In contrast to incipient alveolar bone loss, immigrant background is significantly associated with subgingival calculus among Swedish adolescents.

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