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Patient-related risk factors for tooth loss in aggressive periodontitis after active periodontal therapy

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Abstract

Objectives: Evaluation of patient-related risk factors contributing to tooth loss and recurrence of periodontitis 10.5 years after initial therapy in patients with aggressive periodontitis (AgP).

Material and Methods: Eighty-four of 174 patients were included. Re-examination consisted of patient's history, clinical examination and test for interleukin (IL)-1 composite genotype. Patients' charts were searched for regularity of maintenance and initial diagnosis. Statistical analysis was performed using Poisson and logistical regression analysis.

Results: The responder rate was 48%. Thirteen of 84 patients presented a localized AgP, 68 were females and 29 smoked. One hundred and thirteen teeth out of 2154 were lost after therapy (1.34 teeth/patient). Age ($p = 0.0018$), absence of IL-1 composite genotype ($p = 0.0091$) and educational status ($p = 0.0085$) were identified as statistically significant risk factors for tooth loss. Twenty patients exhibited recurrence of periodontitis at re-examination. Smoking ($p = 0.0034$) and mean Gingival Bleeding Index (GBI) ($p = 0.0239$) contributed significantly to recurrence of disease. No patient participating regularly in supportive periodontal therapy (SPT) showed disease recurrence.

Conclusion: Age, absence of IL-1 composite genotype and low social status are detected as risk factors for tooth loss. Smoking and high mean GBI are associated with an increased risk for recurrence of periodontitis, whereas regular SPT acts as a protective factor.

Key words: age; aggressive periodontitis; recurrence of periodontitis; smoking; social status; supportive periodontal therapy (SPT); tooth loss

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Aggressive periodontitis (AgP) is a rare disease characterized by rapid attachment and bone loss. It commonly affects young individuals with a non-contributory medical history and a familial aggregation (Lang et al. 1999, Armitage 2004). With a prevalence varying between 0.1% and 1.0% in European Caucasians, AgP affects only a minority of all periodontal patients (Albandar & Tinoco 2002, Tonetti & Mombelli 2008), but constitutes a considerable disease because of its severe destruction, which may lead to edentulism early in life (Guerrero et al. 2005).

Conflict of interest and sources of funding statement

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The appropriate treatment of AgP consists of a comprehensive mechanical/surgical therapy that leads to similar results as in patients with chronic periodontitis (ChP) (Lindhe & Liljenberg 1984, Wennström et al. 1986, Buchmann et al. 2002, Kamma & Baehni 2003, Mestnik et al. 2010). However, data concerning treatment outcomes and especially long-term follow-up of AgP patients are limited (Kamma & Baehni 2003). Few clinical studies report results for observation periods of 5 years (Lindhe & Liljenberg 1984, Wennström

et al. 1986, Gunsolley et al. 1995, Buchmann et al. 2002, Kamma & Baehni 2003), but most of these studies refer to the former terms ''early-onset periodontitis'' (EOP) or ''localized juvenile periodontitis'' and consist of rather small sample sizes. Results for longer observation periods than 5 years regarding tooth loss or recurrence of periodontitis are scarce (Saxén et al. 1986).

In the last years, patient-related risk factors for tooth loss during supportive periodontal therapy (SPT) were identified in patients with ChP; e.g. smoking (McGuire & Nunn 1996, Leung et al. 2006), irregular SPT (Checchi et al. 2002, Eickholz et al. 2008), age (Chambrone & Chambrone 2006, Leung et al. 2006) and diabetes mellitus (Faggion et al 2007). Two studies consisting of ChP and AgP patients identified smoking (Dannewitz et al. 2006, Eickholz et al. 2008), age and ineffective plaque control (Eickholz et al. 2008) as risk factors for tooth loss.

Patients suffering from aggressive forms of periodontitis are highly susceptible to disease and may be at a higher risk for recurrent periodontal breakdown following therapy (Kamma & Baehni 2003). Hence, it seems reasonable to ascertain if the afore-mentioned factors prove a similar impact on patients with AgP after active periodontal therapy (APT). To our knowledge, there exists only one study documenting potential risk factors for periodontal disease progression during maintenance (Kamma & Baehni 2003), which exclusively includes patients with EOP.

Therefore, the present study aims at assessing patient-related risk factors contributing to tooth loss and/or recurrence of periodontitis in patients with AgP 10.5 years after APT.

Material and Methods

Patients

Patients with AgP, who had received APT at the Section of Periodontology at the Department of Conservative Dentistry, Clinic for Oral, Dental and Maxillofacial Diseases at the University Hospital Heidelberg from 1992 to 2005, were invited to participate in this study. Treatment always consisted of anti-infective therapy with subgingival debridement under local anaesthesia. In some patients, periodontal surgery was performed. If *Aggregatibacter actinomycetemcomitans* was detected in an individual, antibiotics were prescribed (Van Winkelhoff & Winkel 2005) in addition to subgingival debridement.

All patients fulfilled the following inclusion criteria:

- available panoramic radiograph or full-mouth X-ray status obtained before start of periodontal treatment, which showed inter-proximal bone loss of $\geqslant 50\%$ at two or more teeth;
- a non-contributory medical history at baseline;
- $\leqslant 35$ years at baseline; alternatively < 40 years and rapid bone loss proven by comparison with former radiographs;
- $\geqslant 18$ years at re-examination; and
- completion of APT at least 5 years ago.

The study was approved by the Institutional Review Board for Human Studies of the Medical Faculty of Heidelberg University (Application #033/2009). All patients were informed on risks and benefits as well as the procedures of the study and gave written informed consent.

Clinical examination

Re-examination took place from April 2009 to May 2010 and was conducted by an independent examiner (A. B.), who had never seen the patients before.

It included:

- medical history;
- self-reported comprehensive smoking history [German Cancer Research Center (DKFZ)]. Additionally, patients were categorized as current, former and non-smokers. Patients who had quit smoking at least 5 years ago were classified as former smokers. Non-smokers had never smoked in their lives (Lang & Tonetti 2003);
- family history of periodontal disease;
- dental status;
- periodontal pocket depth (PPD) and vertical attachment levels (PAL-V) to the nearest 1 mm using a manual periodontal probe (PCPUNC 15; HuFriedy, Chicago, IL, USA) at six sites per tooth;
- bleeding on probing (BOP) and suppuration on probing were assessed;
- assessment of furcation involvement (Hamp et al. 1975) at multi-rooted teeth using a Nabers probe marked in 3 mm increments (PQ2N; HuFriedy);
- Gingival Bleeding Index (GBI) (Ainamo & Bay 1975) and Plaque Control Record (PCR) (O'Leary et al. 1972);
- test for interleukin (IL)-1 composite genotype using a test kit (GenoType PRT Parodontitis-Risiko-Test, Hain Lifescience GmbH, Nehren, Germany). To sample cells, a foam swam was moved over cheek mucosa for 20 s and then sent to the laboratory for analysis. A patient was classified as IL-1 composite genotype positive (Kornman et al. 1997) if IL-1A allele $-$C889T (rs1800587) and IL-1B allele $+$C3953T (rs1143 634) were present;
- self-reported actual body weight and body height to calculate the patient's body mass index (BMI); and
- self-reported patient's educational status and classification into three groups corresponding to education: low ($\leqslant 9$ years in school), moderate (apprenticeship, college) and high (university degree).

Evaluation of patients' charts

Evaluation of patients' charts was accomplished by two examiners (A. B. and N. E. S.) independently. Retrospectively, a baseline diagnosis [localized AgP (LAgP) or generalized AgP (GAgP)] was assigned to each patient according to the actual classification of periodontal diseases (Armitage 1999).

Tooth loss during SPT, the main outcome variable of this study, was defined by comparison of the dental status at re-evaluation (first SPT appointment) and at re-examination.

Regularity of SPT at the Section of Periodontology at the University Hospital Heidelberg was documented. A frequency of at least two visits per year was recommended. If someone had extended the recall interval once over 100% (i.e. returning after 13 months for SPT), the patient was plunged into the irregular SPT group (Eickholz et al. 2008).

The mean value for GBI and PCR documented during SPT was calculated.

SPT

During each SPT session, GBI and PCR were assessed. The patient was re-instructed and re-motivated to an effective individual plaque control. Professional tooth cleaning followed as

well as application of a fluoride gel. Twice a year, the dental status was obtained and PPD, PAL-V and BOP were surveyed at four or six sites per tooth. Sites exhibiting PPD of 4 mm and BOP as well as sites with PPD $\geqslant$5 mm were scaled subgingivally.

Recurrence of periodontitis

In accordance with good clinical practice at the Section of Periodontology at the University Hospital in Heidelberg, recurrence of periodontitis was considered, if $>$30% of a patient's teeth owed to be re-instrumented subgingivally (PPD$\geqslant$5 mm). In these cases, the necessity of a recurrent periodontal therapy was explained.

Statistical analysis

All data were entered by two investigators (A. B. and N. E. S.) into two separate data files (Excel version 2003, Microsoft Corporation, Redmond, WA, USA), which were then combined into one. All differing entries were double-checked by means of comparison with the original patient's charts and corrected.

The patient was looked upon as a statistical unit and tooth loss during SPT was defined as the main outcome variable. Recurrence of periodontitis formed the second outcome variable.

Descriptive statistics was performed using a computer program (SPSS, Version 18, SPSS Inc., Chicago, IL, USA). Poisson regressions were modelled by an independent statistician (P. R.) using another program (SAS® version 9.1, SAS Institute, Cary, NC, USA).

With Poisson regression factors influencing the dependent variable, tooth loss (a rare event) should be identified. Poisson regression was used, as the main outcome ''number of lost teeth'' represents a count variable. Variables assessed at re-examination were entered into the first model [sex, age, BMI, educational status, diagnosis at baseline (localized *versus* generalized AgP), IL-1 composite genotype, smoking habit (current *versus* former *versus* non-smoking), compliance with recommended SPT attendance, status of oral hygiene according to mean GBI and PCR during SPT]. After identification of dichotomous factors, means, standard deviations, medians and ranges for tooth loss of the respective groups were calculated.

For the binary variable, ''recurrence of periodontitis'' logistic regression was applied using the same variables but exchanging the dependent variable for recurrence of disease, the second outcome variable.

Third molars were excluded from analysis.

Results

Patients

A total of 174 patients with localized or generalized AgP, which were treated at the Section of Periodontology at the University Hospital Heidelberg, who conformed to the inclusion criteria, could be detected retrospectively. Ninety patients were not willing or able to be re-examined; the reasons for their refusal are listed in Fig. 1. Finally, 84 of 174 patients participated in the study, which results in a responder rate of 48%.

At initiation of therapy, the patients of this study were aged 20–36 years (mean age 30.8 $\pm$ 4.1) and exhibited 2154 teeth at the start of SPT. Eighty-two patients were of Caucasian origin, one individual was of Asian (Japanese) and one of African (Central Africa) origin. 64.3% reported a positive family history of periodontitis (Table 1).

According to Table 1, the average re-evaluation period after APT was 10.5 years (5–17 years), mean GBI during SPT 3.9 $\pm$ 3.7% (range 0–21.5%) and mean PCR during SPT 26.1 $\pm$ 14.2% (range 3.9–100%). Sixty-eight of the re-examined patients were females, 13 exhibited a localized form of AgP at baseline and 24 participated regularly in SPT. Twenty-six individuals showed a positive IL-1 composite genotype, which quite exactly represents the prevalence of 33% in central Europe (De Sanctis & Zucchelli 2000). Six patients exhibited a low social status referring to their education and 29 patients (34.5%) were current smokers being in accordance with the German population in that age group (Statistisches Bundesamt 2009: http://www.destatis.de); whereas, the LAgP group showed an increased amount of smokers (54%) (Table 1).

Chi-square testing revealed an uneven distribution ($p<0.05$) of patients according to gender, initial diagnosis, IL-1 composite genotype, regularity of maintenance and social status.

Tooth loss

During APT, 53 teeth were extracted and 113 further teeth were lost during SPT. This represents a mean total tooth loss of 0.63 teeth/patient during APT and 1.34 teeth/patient during SPT. However, tooth loss was not distributed evenly. Less than half of the patients exhibited tooth loss during SPT and only a few individuals lost more than three teeth (Table 2).

Poisson regression analysis identified age ($p = 0.0018$), IL-1 composite genotype ($p = 0.0091$) and educational status ($p = 0.0085$) as statistically significant factors influencing tooth loss. Patients with a short education ($\leqslant$9 years at school) showed a 3.74-fold increased risk for tooth loss compared with

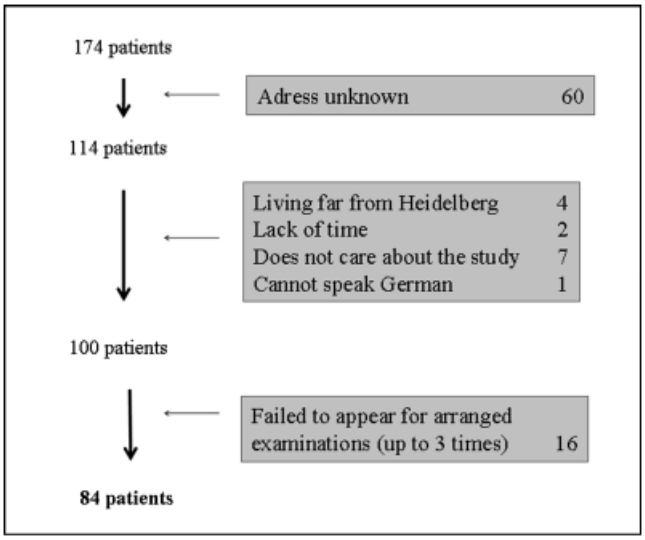

Fig. 1. Recruitment of patients.

Table 1. Patient characteristics

	Total ($n = 84$)	LAgP ($n = 13$)	GAgP ($n = 71$)
Sex (female)	68 (80.9%)	9 (69.2%)	59 (83.1%)
Age	30.78 ± 4.06	28.08 ± 4.29	31.28 ± 3.85
Teeth at beginning of SPT	$n = 2154$	$n = 344$	$n = 1810$
Teeth per subject	25.64 ± 3.27	26.46 ± 1.98	25.49 ± 3.45
Smoking			
Current smoker	29 (34.5%)	3 (23.1%)	26 (36.6%)
Former smoker	21 (25.0%)	4 (30.8%)	17 (24.0%)
Non-smoker	34 (40.5%)	6 (46.1%)	28 (39.4%)
SPT			
Regular	24 (28.6%)	4 (30.8%)	20 (28.2%)
Irregular	60 (71.4%)	9 (69.2%)	51 (71.8%)
IL-1 composite genotype			
Absence	58 (69.0%)	8 (61.5%)	50 (70.4%)
Presence	26 (31.0%)	5 (38.5%)	21 (29.6%)
Educational status			
Low	6 (7.1%)	1 (7.7%)	5 (7.0%)
Moderate	54 (64.3%)	7 (53.8%)	47 (66.2%)
High	24 (28.6%)	5 (38.5%)	19 (26.8%)
BMI	23.61 ± 3.84	23.00 ± 4.22	23.70 ± 5.51
Mean GBI	3.9 ± 3.7%	6.17 ± 4.80	3.49 ± 3.12
Mean PCR	26.1 ± 14.18%	24.50 ± 8.41	26.59 ± 15.15
Familial history of periodontitis (known)			
Relatives	54 (64.3%)	6 (7.1%)	48 (57.2%)
Father	19 (22.6%)	2 (2.4%)	17 (20.2%)
Mother	39 (46.4%)	4 (4.8%)	35 (41.6%)
Others (siblings, grandparents)	16 (19.1%)	1 (1.2%)	15 (17.9%)
Duration of SPT (range) (years)	10.54 (5–17)	10.40 (6–15)	10.70 (5–17)

SPT, supportive periodontal therapy; IL-1, interleukin-1; BMI, body mass index; GBI, Gingival Bleeding Index; PCR, plaque control record; AgP, aggressive periodontitis.

Table 2. Tooth loss per patient during SPT

Tooth loss	Number of patients ($n = 84$)	LAgP ($n = 13$)	GAgP ($n = 71$)
No tooth	44 (52.4%)	12	32
1 tooth	17 (20.2%)	–	17
2 teeth	7 (8.3%)	–	7
3 teeth	7 (8.3%)	1	6
4 teeth	2 (2.4%)	–	2
5 teeth	3 (3.6%)	–	3
6 teeth	1 (1.2%)	–	1
7 teeth	1 (1.2%)	–	1
9 teeth	1 (1.2%)	–	1
16 teeth	1 (1.2%)	–	1
	40 (113 teeth)	1 (3 teeth)	39 (110 teeth)

SPT, supportive periodontal therapy; AgP, aggressive periodontitis.

patients with a university degree. Patients with absent IL-1 composite genotype exhibited a significantly higher risk for tooth loss than those presenting the IL-1 composite genotype.

Other factors [baseline diagnosis ($p = 0.0713$), smoking ($p = 0.0628$), regularity of SPT ($p = 0.09$) and mean PCR ($p = 0.0856$)] slightly failed to show statistical significance (Table 3). The baseline diagnosis ''GAgP'' indicated a threefold higher risk for tooth loss (RR: 3.10) than ''LAgP'' and a 10% increase of PCR was associated with a risk ratio of 3.19 for loosing teeth. Non-smokers and former smokers seemed protected against tooth loss compared with smokers (0.82 ± 1.59 *versus* 0.81 ± 1.25 *versus* 2.34 ± 3.42 teeth lost). Furthermore, patients who regularly attended SPT lost fewer teeth than those who failed regular appearance (0.79 ± 1.18 *versus* 1.57 ± 2.74 teeth) (Table 4).

Spurious associations regarding the main outcome variable tooth loss were denied by testing interactions in the model.

Recurrence of periodontitis

Twenty patients of the whole sample showed recurrence of periodontitis at re-examination (24%). Statistically significant factors contributing to recurrence of the disease were smoking ($p = 0.0034$) and mean GBI during SPT ($p = 0.0239$). Each second smoker showed recurrence of periodontitis, whereas just each fifth former smoker and each 20th non-smoker were affected. This represents a tenfold increased risk for smokers to suffer from recurrence of disease (Table 5). Furthermore, the baseline diagnosis ''GAgP'' revealed an odds ratio of 35.2 compared with the baseline diagnosis ''LAgP'', where just in one of 13 cases a recurrence of periodontitis occurred. Also, an increased mean PCR implied a heightened risk for recurrence of the disease (odds ratio: 63.81). Sex, IL-1 composite genotype and insurance status seemed to be irrelevant with regard to recurrence of periodontitis (Table 5).

Patients who showed recurrence of periodontitis at re-examination exhibited a high tooth loss rate during SPT, as well. In these 20 patients (24% of the sample), 57 teeth were extracted, which represents half of all teeth (50.4%) lost in the whole study sample.

None of the patients who participated regularly in SPT showed recurrence of the disease at re-examination (Table 6).

Discussion

Patients

AgP with its primary features (1) except for the presence of periodontitis patients are clinically healthy, (2) rapid attachment loss and bone destruction and (3) familial aggregation presents a rare disease (Lang et al. 1999, Armitage 2004, Tonetti & Mombelli 2008). It may be difficult to determine the second and the third primary feature. Thus, the selection of patients in this retrospective study followed well-established inclusion criteria (Kim et al. 2006, Fiebig et al. 2008); a non-contributory medical history at baseline, inter-proximal bone loss of $\geqslant 50\%$ at least at two teeth and not older than 35 years of age. If rapid bone loss could be proven by comparison with older radiographs, patients <40 years of age were included, as well (four individuals). Many patients could give information on periodontally diseased relatives (64%), mostly from the mother's side. However, because of the fact that self-reporting is a rather arguable criterion, familial history was not implied as a mandatory inclusion criterion.

Not only patients still being treated at the Section of Periodontology at the University Hospital of Heidelberg were

Table 3. Poisson regression analysis: tooth loss after active periodontal treatment (APT) in relation to patient-related factors

	Estimate	SE	*t*	*p*	Risk ratio
Intercept	− 7.0610	1.5919	− 4.44	< 0.0001	
Sex (female)	− 0.0278	0.4236	− 0.07	0.9479	0.97
Age (1 year)	0.1161	0.6168	2.62	0.0108	1.12
Diagnosis (GAgP)	1.1303	0.6168	1.83	0.0713	3.10
Smoking				0.0628	
Non-smoker	0	–	–	–	1.00
Former smoker	− 0.2412	0.3473	− 0.69	0.4898	0.79
Current smoker	− 0.4881	0.2856	1.71	0.0920	1.63
Irregular SPT	0.5112	0.2972	1.72	0.0900	1.67
Absence of IL-1 composite genotype	− 0.8909	0.3317	− 2.69	0.0091	0.41
Body mass index	0.0447	0.0333	1.34	0.1840	1.05
Mean gingival bleeding index	0.3448	3.2055	0.11	0.9147	1.41
Mean plaque control record (10% step)	1.1600	0.6649	1.74	0.0856	3.19
Educational status				0.0085	
Low	1.3187	0.5091	2.59	0.0118	3.74
Moderate	0.8968	0.3102	2.89	0.0052	2.45
High	0	–	–	–	1.00
State insurance	− 0.2854	0.4348	− 0.66	0.5139	0.75

Dependent variable: tooth loss after APT ($n = 84$).

SPT, supportive periodontal therapy; AgP, aggressive periodontitis; IL-1, interleukin-1.

Table 4. Tooth loss per patient over a mean period of 10.5 years of supportive periodontal therapy (SPT)

	N	Mean ± SD
Total	84	1.34
Sex		
Female	68	1.49 ± 2.58
Male	16	0.75 ± 1.44
Initial diagnosis		
LAgP	13	0.23 ± 0.83
GAgP	71	1.55 ± 2.56
Smoking		
Current smoker	29	2.34 ± 3.42
Former smoker	21	0.81 ± 1.25
Non-smoker	34	0.82 ± 1.59
SPT		
Regular	24	0.79 ± 1.18
Irregular	60	1.57 ± 2.74
Interleukin-1 composite genotype		
Absence	68	1.53 ± 2.76
Presence	26	0.92 ± 1.32
Educational status		
Low	6	4.60 ± 6.66
Moderate	54	1.38 ± 1.93
High	24	0.58 ± 1.32
Insurance status		
State	74	1.43 ± 2.54
Private	10	0.70 ± 1.06

AgP, aggressive periodontitis; SPT, supportive periodontal therapy.

included in this study but also patients who had quit treatment there due to various reasons (e.g. relocation, continuation of therapy at other dentists). Although some patients who quit treatment at the University Hospital of Heidelberg received maintenance care with his or her family dentist, our analysis only considers compliance with the specialist-based SPT.

Conspicuously, most patients of the sample were females (80.9%). It is well known that females are more likely to seek medical and dental treatment. Hence, most clinic- or practice-based studies included more women than men, although prevalence of AgP is not higher in females (Marazita et al. 1994).

Tooth loss

There are few longitudinal studies reporting on tooth loss in patients with AgP. Most of them describe the maintenance after treatment of EOP and exhibit observation periods of $\leqslant 6$ years in rather small sample sizes (Gunsolley et al. 1995, Kamma & Baehni 2003). To our best knowledge, just one study with a longer follow-up (8.4 years) by Saxén et al. (1986) exists, in which the mean tooth loss during the study period amounted to 0.11 teeth/year.

In our retrospective clinical trial, similar results were found: tooth loss during the observation period (10.5 years after APT) amounted to 0.13 teeth/year; out of 2154 teeth, only 133 got lost (0.6%). Thus, tooth loss occurred quite rarely. Splitting the participants regarding their initial diagnosis, patients with GAgP lost 0.14 teeth/year, whereas tooth loss in individuals with LAgP added up to only 0.02 teeth/year.

In a 5-year follow-up by Kamma & Baehni (2003), 25 EOP patients received APT followed by SPT every 3–6 months. The mean annual tooth loss added up to 0.20 teeth/year and 36% of all patients (9 of 25) lost no tooth. A control group of patients without regular SPT was missing in both of the aforementioned studies. Gunsolley et al. (1995) documented an even more considerable tooth loss in patients with EOP (0.29 teeth/year). This can be explained by the patient sample; in our study, all individuals at least completed APT at a specialist-based centre; in the study by Gunsolley et al. (1995), some patients received no periodontal therapy. Besides, ethnical origin in both studies differs.

By comparing tooth loss in ''AgP'' and ''ChP'', similar results can be found in a study by Eickholz et al. (2008), where patients with mostly ChP (90%) lost 0.155 teeth per patient annually. Considering just the samples with regular SPT, both studies represent similar tooth loss rates; in our study, patients with regular SPT lost 0.075 teeth/year, whereas Eickholz et al. (2008) documented a tooth loss of 0.055 teeth/year. Another study by König et al. (2001) showed similar results in a sample of ChP patients with regular SPT (0.066 teeth/year). Hence, tooth loss in AgP patients after APT is not distinguishable from patients with ChP in a long-lasting observation period.

Similar to previous studies focusing on ChP, the present study tried to define risk factors for tooth loss in AgP. The factors age, low educational status and absence of IL-1 composite genotype were identified to be significantly correlated with tooth loss.

Owing to the fact that results concerning risk factors for tooth loss in AgP have not been established, yet, just a comparison with ChP is feasible; in a recent review by Chambrone et al. (2010), age and smoking emerged to be associated with tooth loss during SPT. In accordance to these results, increased age could also be identified as risk factor for tooth loss, whereas smoking just slightly evaded statistical significance.

Evidence to implicate a specific IL-1 genotype as a risk factor in AgP is limited (Grigoriadou et al. 2010). In the present retrospective clinical trial,

Table 5. Logistic regression analysis: recurrence of periodontitis after active periodontal treatment (APT)

	Estimate	SE	*t*	*p*	Odds ratio
Intercept	− 4.5519	4.3310	− 1.05	0.2970	0.01
Sex (female)	− 1.2844	1.1654	− 1.10	0.2743	0.28
Age (1 year)	0.0504	0.1068	0.47	0.6385	1.05
Diagnosis (GAgP)	3.5610	1.9261	1.85	0.0688	35.20
Smoking				0.0034	
Non-smoker	− 4.7093	1.3633	− 3.45	0.0010	0.01
Former smoker	− 2.9473	1.1876	− 2.48	0.0155	0.05
Current smoker	0	–	–	–	1.00
Absence of IL-1 composite genotype	− 1.0738	0.9715	− 1.11	0.2730	0.34
Body mass index	0.0349	0.1107	0.32	0.7536	1.04
Mean gingival bleeding index	26.4608	11.4547	2.31	0.0239	31.1
Mean plaque control record (10% step)	4.1560	3.7851	1.10	0.2761	63.81
Educational status				0.1417	
Low	− 1.0638	1.5794	− 0.67	0.5029	0.35
Moderate	− 1.8236	0.9098	− 2.00	0.0490	0.16
High	0	–	–	–	1.00
State insurance	− 0.1527	1.1428	− 0.13	0.8941	0.86

Dependent variable: recurrence of periodontitis after APT ($n = 84$).
AgP, aggressive periodontitis.

Table 6. Distribution of recurrence of periodontitis

	n	Incidence
Total	84	20 (23.8%)
Sex		
Female	68	16 (23.5%)
Male	16	4 (25.0%)
Initial diagnosis		
LAgP	13	1 (7.7%)
GAgP	71	19 (26.8%)
Smoking		
Current smoker	29	14 (48.3%)
Former smoker	21	4 (19.0%)
Non-smoker	34	2 (5.9%)
SPT		
Regular	24	0 (0.0%)
Irregular	60	20 (33.3%)
Interleukin-1 composite genotype		
Absence	68	14 (24.6%)
Presence	26	6 (23.1%)
Educational status		
Low	5	3 (60.0%)
Moderate	54	9 (16.7%)
High	24	8 (33.3%)
Insurance status		
State	74	18 (24.3%)
Private	10	2 (20.0%)

AgP, aggressive periodontitis; SPT, supportive periodontal therapy.

presence of IL-1 composite genotype seemed to act as a protective factor regarding tooth loss. Fiebig et al. (2008) could not detect an association between variants in the IL-1 gene cluster and AgP in a large cohort of 415 European Caucasian patients. No association between IL-1A, IL-1B and IL-1RN and AgP could be detected in a recent study by Scapoli et al. (2010), either.

Likewise, the duration of an individual's education represented a risk factor for tooth loss. Participants with a university degree lost significantly fewer teeth than patients with <9 years of education. This coincides with the Study of Health in Pomerania including 3146 participants (Kocher et al. 2005), whose authors documented a low educational level as risk determinant for attachment and tooth loss. On the other hand, a review by Klinge & Norlund (2005) concludes that socio-economic variables associated with periodontal disease present a less important factor than smoking; but the main outcome variable in all included studies was attachment or bone loss compared with tooth loss in our study. A reason for fewer tooth loss in highly educated patients might be their improved compliance (Demetriou et al. 1995).

Although slightly failing statistical significance, tooth loss in LAgP following therapy appears to differ from tooth loss in GAgP. Whereas just one patient with LAgP lost teeth, tooth loss occurred in more than half of the sample with GAgP. Thus, the initial diagnosis ''GAgP'' was associated with a threefold increased risk for tooth loss compared with ''LAgP''. In accordance with the results of a case series by Mros & Berglundh (2010) and a study by Gunsolley et al. (1995), the ''LAgP'' was associated with rare tooth loss. This might emphasize the thesis of Armitage (2004) that LAgP represents not merely a localized form of GAgP. Another possible explanation according to Pretzl et al. (2008) might be given; increased initial bone loss indicated a higher probability for future tooth loss, which puts more teeth at risk in GAgP.

The fact that smoking influences periodontal treatment outcomes has been clearly established (Kamma & Baehni 2003, Hughes et al. 2006). In the present study, smokers lost 2.34 teeth during SPT, whereas non-smokers and former smokers lost considerably fewer teeth (0.82 and 0.81 teeth). However, smoking as well as irregularity of SPT and higher mean PCR slightly failed statistical significance.

Patients complying with the recommended SPT interval lost fewer teeth than those who appeared irregularly. However, compared with results from a recent study including ChP and AgP patients (Eickholz et al. 2008), the influence of this factor in a sample with just AgP seems to be smaller than expected. A possible explanation might be the small sample size or the fact that genetic components are more emphasized and obscure regularity of SPT as a risk factor.

Recurrence of periodontitis

Periodontal therapy represents an effective tool to maintain periodontal structures in localized and generalized AgP and can lead to long-term stability (Lindhe & Liljenberg 1984, Saxén et al. 1986, Wennström et al. 1986, Buchmann et al. 2002, Kamma & Baehni 2003). Most of the mentioned studies handle with the former diagnosis EOP and consist of small sample sizes of up to 25 patients (Lindhe & Liljenberg 1984, Saxén et al. 1986, Wennström et al. 1986, Kamma & Baehni 2003). The only trial focusing on periodontal therapy and maintenance in patients with AgP reports that in 95% of all cases disease progression could be stopped, while 2–5% elicited discrete or recurrent episodes of loss of periodontal support over a 5-year period (Buchmann et al. 2002). In this prospective follow-up, 13 patients received APT followed by SPT three to four times per year. Information on tooth loss was not given and a control group without regular SPT was missing.

In the present study, recurrence of periodontitis represents the secondary outcome variable and was defined as occurrence of PPD of $\geqslant 5$ mm at $\geqslant 30\%$ of all teeth at re-examination. Another criterion proposed for periodontitis progression by Tonetti & Claffey (2005), in which $\geqslant 2$ teeth demonstrate a longitudinal loss of proximal attachment of $\geqslant 3$ mm could not be taken into account due to the fact that clinical attachment levels at baseline were not measured routinely before 1999.

Smoking was detected as a main statistically significant risk factor for the recurrence of periodontitis. More than half of the current smokers showed a recurrence of disease at re-examination and had a tenfold increased risk for a relapse compared with non-smokers. This coincides with the results by Kamma & Baehni (2003).

Baseline diagnosis represents a further risk indicator for recurrence of periodontitis. Although, it slightly failed to show statistical significance ($p = 0.06$), GAgP with an odds ratio of 35.2 could indicate a substantial risk for recurrence. Whereas, just one patient with LAgP experienced recurrence of disease (8%), 19 individuals with GAgP showed recurrence. This is endorsed by two further studies (Gunsolley et al. 1995, Mros & Berglundh 2010), which present stable long-term results for LAgP or rather localized EOP after APT, regardless of other potential risk factors. To underline that the localized form of AgP can be stopped in most cases by APT and tooth loss occurs rarely, further studies are necessary.

Furthermore, an elevated mean GBI during SPT represents a statistically significant risk factor for recurrence of the disease and a heightened mean PCR score shows a strongly increased risk (OR 63.8), as well. These results coincide with findings by Eickholz et al. (2008), who report an increased risk for a worse periodontal status in ChP and AgP patients with increased mean plaque scores.

Also, SPT appears to be a factor with essential influence. No patient receiving regular SPT obtained a recurrence of periodontitis. Thus, to inhibit recurrence of the disease maintenance at a specialist-based centre represents a truly effective tool. Owing to the fact that no patient complying with the recommended SPT intervals experienced recurrence, this factor could not be entered into the statistical analysis because it would have confounded all other contributing factors.

Sex, IL-1 composite genotype and insurance status were not relevant with regard to recurrence of periodontitis.

Bias protection

As recommended by Chambrone et al. (2010), bias protection was a major issue. To impede bias as far as possible, the investigator who conducted all re-examinations (A. B.) did not in any way take part in the active treatment. Additionally, the second examiner (N. E. S.) was blinded regarding any therapy. Protection from selection bias was maintained, because patient recruitment followed a strict scheme.

Despite all effort, there still remains a high risk of bias because of the high drop-out rate of 52%. Besides, patients who could not be reached (e.g. changes in name or address), there were some who refused participation in the study. A higher tooth loss rate in those individuals might be assumed, e.g. because of lost interest in teeth and their therapy resulting in extractions.

Regarding the relatively low number of patients in our study in relation to the amount of included risk factors, confounding and effect modification could distort the results. Therefore, the Poisson regression analysis was re-assessed a second time just with the statistically significant factors as well as the factor gender. Compared with our first analysis, effect modification did not vary strongly and kept its direction, which underlines the robustness of calculation. It also gives a hint that possible confounding did not strain the results substantially.

Besides, this study presents a high complexity of outcome measures and explanatory variables. Whereas tooth loss is a true clinical endpoint, the factors that determine it are complex and could change during the long observation period (e.g. smoking status, oral hygiene). Finally, the decision for extraction remains with the individual dentist, who is likely to define hopeless teeth individually (Zaher et al. 2005).

Conclusion

After completion of APT in patients with AgP, age, educational status and absence of IL-1 composite genotype represent statistically significant risk indicators for tooth loss. Regular SPT and nicotine abstinence reduce the risk for recurrence of periodontitis on a long-term basis. High mean GBI scores after active therapy elevate the risk for recurrence of the disease.

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Clinical Relevance

Scientific rationale for the study: Long-term retention of teeth in function is the ultimate goal of periodontal therapy. This study aims to assess factors contributing to tooth loss and recurrence of periodontitis after active therapy in patients with AgP.

Principal findings: The following predictive factors for tooth loss in patients with AgP after APT could be detected: age, educational status and absence of IL-1 composite genotype. Recurrence of periodontitis was mainly found in smokers and patients with a high GBI during SPT.

Practical implications: Dentists and patients suffering from AgP need to know which factors may lead to tooth loss during SPT and how to maintain a favourable periodontal status after initial therapy.