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Tooth loss after active periodontal therapy. 1: patient-related factors for risk, prognosis, and quality of outcome

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Abstract

Objectives: Assessment of patient-related factors contributing (1) to tooth loss and (2) to the quality of treatment outcome 10 years after initiation of anti-infective therapy.

Material and Methods: All patients who had received active periodontal treatment 10 years ago by the same examiner were recruited consecutively until a total of 100 patients were re-examined. Re-examination was performed by a second examiner and included clinical examination, test for interleukin-1 (IL-1) polymorphism, smoking history, review of patients' files (e.g. regularity of supportive periodontal therapy: SPT). Statistical analysis included Poisson and logistic regressions.

Results: Fifty-three patients attended SPT regularly, 59 were females, 38 were IL-1 positive. Poisson regressions identified mean plaque index during SPT ($p < 0.0001$), irregular attendance of SPT ($p < 0.0001$), age ($p < 0.0001$), initial diagnosis ($p = 0.0005$), IL-1 polymorphism ($p = 0.0007$), smoking ($p = 0.0053$), and sex ($p = 0.0487$) as factors significantly contributing to tooth loss. Additionally, mean plaque index during SPT ($p = 0.011$) and irregular SPT ($p = 0.002$) were associated with a worse periodontal status 10 years after initiation of therapy.

Conclusion: The following risk factors for tooth loss were identified: ineffective oral hygiene, irregular SPT, IL-1 polymorphism, initial diagnosis, smoking, age and sex.

Key words: interleukin-1 polymorphism; long-term success after systematic periodontal therapy; periodontal risk factors; supportive periodontal therapy (SPT); tooth loss

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The aim of periodontal therapy is the long-term retention of natural teeth in a healthy, functional, aesthetically acceptable, and painless state (Hirschfeld & Wasserman 1978, Schweizerische Zahnärzte-Gesellschaft 2000). Particularly for patients under supportive periodontal therapy (SPT), attachment loss and tooth loss quite rarely occur. However, attachment and tooth loss are not distributed equally among patients, but accumulate in distinct at-risk patients (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989). In the past, classification of at-risk patients was predominantly based on retrospectively observed tooth loss (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989). These retrospective observations do not allow prognosis that may be used to influence therapeutic decisions. Some factors characterizing periodontal at-risk patients are already known, e.g. smoking (McGuire & Nunn 1996, Chambrone & Chambrone 2006, Dannewitz et al. 2006, Leung et al. 2006), irregular SPT (Checchi et al. 2002), diabetes mellitus (Faggion et al. 2007), and age (Chambrone & Chambrone 2006, Leung et al. 2006). The influence of the polymorphism in the interleukin (IL)-1α (-889) and IL-1β ($+3953$) gene clusters is still controversial (Ehmke et al. 1999, McGuire & Nunn 1999, Laine et al. 2001, Huynh-Ba et al. 2007).

Conflict of interest and source of funding statement

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Earlier retrospective studies either re-examined only patients who still were under regular therapy at the study site or gave no information on the responder rate (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Checchi et al. 2002, Fardal et al. 2004, Muzzi et al. 2006). Most retrospective analyses report that patients had attended SPT throughout the whole period before re-examination (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Fardal et al. 2004, Muzzi et al. 2006, Carnevale et al. 2007a, b, Faggion et al. 2007). However, for the effect of SPT to be revealed, a control group of non-compliant patients is required.

Some studies have reported surrogate variables as probing pocket depths (PPD), attachment level (PAL), and recurrence of pockets, respectively (König et al. 2001, Carnevale et al. 2007a). However, the ultimate goal of dental treatment is to avoid and to prevent tooth loss (Hirschfeld & Wasserman 1978). Thus, tooth loss is the most relevant parameter to evaluate the efficacy of dental treatment: a true clinical end point (Hujoel et al. 1999, Tonetti et al. 2000, Hujoel 2004).

The aim of this study was to assess (1) patient-related factors contributing to tooth loss and quality-of-treatment outcome 10 years after initiation of anti-infective therapy and (2) strategies to prevent tooth loss.

Material and Methods

Patients

All patients who fulfilled the following criteria:

- periodontal treatment (antiinfective therapy with subgingival debridement under local anaesthesia and if required periodontal surgery) at the Section of Periodontology at the Department of Conservative Dentistry, Clinic for Oral, Dental, and Maxillofacial Diseases at the University Hospital Heidelberg beginning in October 1992 by the same trained periodontist (P. E.).
- X-ray status obtained before periodontal treatment

were consecutively recruited 10 years ± 6 months after initiation of therapy (first appointment of periodontal treatment) for this study until 100 qualifying patients had been included. We had decided to adopt the sample size already used by other authors (McFall 1982, McGuire & Nunn 1996, Fardal et al. 2004). The study was approved by the Institutional Review Board for Human Studies of the Medical Faculty of Heidelberg University (Application# 331/2002). All participating patients were informed on risks and benefits as well as on the procedures of the study and gave written informed consent.

Clinical examinations

All re-examinations were performed by an independent examiner (B. P.) from January 2003 to May 2006 and encompassed the following information:

- Comprehensive smoking history [German Cancer Research Center (DKFZ) smoking history].
- Medical history. Patients were categorized according to self-reported diabetes mellitus.
- Dental status.
- Gingival bleeding index (GBI; Ainamo & Bay 1975) and plaque control record (PCR; O'Leary et al. 1972).
- PPD and vertical attachment levels (PAL-V) to the nearest 1 mm using a manual periodontal probe (PCPUNC 15; Hu Friedy, Chicago, IL, USA) at six sites per tooth, bleeding on probing (BOP) after 30 s, and suppuration on probing (SUP).
- At multi-rooted teeth, assessment of furcation involvement (Hamp et al. 1975) using a Nabers probe that was marked in 3 mm increments (PQ2N; Hu Friedy).
- Test for IL-1 polymorphism (IL-1A –889, IL-1B +3953) (IAI ParoGen Test, IAI Institut für Angewandte Immunologie, Zuchwil, Switzerland). In some patients IL-1 polymorphism had been tested during routine SPT to estimate the individual periodontal risk and SPT interval. In these cases a commercially available test kit was used (GenoType PRT Parodontitis-Risiko-Test, Hain Life Science GmbH, Nehren, Germany). A patient was classified as IL-1 positive if both the second allele for IL-1A and IL-1B was positive. To evaluate the dependability of both laboratories in 10 patients, both tests were used.
- All patients who had lost teeth were asked for the reasons (e.g. caries, endodontic, periodontal, orthodontic, prosthetic, trauma, etc.).
- All patients were asked about satisfaction with the aesthetic aspects of their periodontal situation. They were asked to score their satisfaction by giving school marks: 1 = excellent, 2 = good, 3 = satisfactory, 4 = fair, 5 = poor.

According to self-reported smoking history, patients were categorized as current, former, and never smokers. Never smokers were patients who had never smoked in their lives. Patients who had quit smoking for at least 5 years were looked upon as former smokers. All other patients were classified as current smokers (Lang & Tonetti 2003).

Evaluation of radiographs

Before active periodontal treatment (subgingival debridement and if necessary periodontal surgery), complete sets of periapical radiographs (Ultraspeed; Kodac, Rochester, NY, USA) of each patient were obtained by the XCP technique using film holders (XCP, Kentzler & Kaschner Dental, Ellwangen/Jagst, Germany). Intra-oral size 0 (maxillary canines and mandibular anteriors) and 2 (all other regions) dental films were exposed to an X-ray source (Heliodent 70®, 70 kV, 7 mA, Sirona, Bensheim, Germany) and developed under standardized conditions (Periomat®, Dürr Dental, Bietigheim-Bissingen, Germany).

All radiographs were viewed in a darkened room using a radiograph screen (67-0420, Dentsply Rinn, Elgin, IL, USA). Relative bone loss in per cent was assessed at the periodontally most affected site of each tooth using a Schei ruler (Schei et al. 1959) and assigned to one of three groups (<50%, 50–75%, >75%).

According to the clinical and radiographic findings, each tooth was assigned to one of three prognostic groups (Checchi et al. 2002):

- *hopeless*: bone loss >75% or teeth that had at least two characteristics of ''questionable'' category;
- *questionable*: bone loss between 50% and 75% or the presence of an angular defect (infrabony component >2 mm) or furcation involvement;
- *good*: bone loss <50% or not fitting one of the two previous categories.

Table 1. Form for the assessment of the individual periodontal risk (modified according to Ramseier & Lang 1999)

1	2	3	4	5	6	7
Control the risk factors and mark the respective threshold values in columns 2–7	Low risk		Moderate risk		High risk	
					Date:	
1. Bleeding on probing (BOP) (%)	⩽4	5–9	10–16	17–24	25–35	⩾36
2. Number of sites with PPD⩾5 mm	⩽2	3–4	5–6	7–8	9	⩾10
3. Number of lost teeth (without third molars)	⩽2	3–4	5–6	7–8	9	⩾10
4. Bone loss (index)	⩽0.25	0.26–0.5	0.51–0.75	0.76–1.0	1.1–1.24	⩾1.25
5. Cigarette consumption	Never smoker	Former smoker	⩽10/day	10–19/day	⩾20/day	

Preliminary risk assessment →	Low risk	Moderate risk	High risk
6. Systemic/genetic factors:	Factor absent	Factor not noted	Factor present
Diabetes mellitus HIV infection Gingival/periodontal manifestation of systemic diseases Interleukin-1β polymorphism			

Definitive risk assessment →	Low risk	Moderate risk	High risk
Low periodontal risk 1 SPT per year	Moderate periodontal risk 2 SPT per year	High periodontal risk	3–4 SPT per year

This form provides a basis for the assessment of the periodontal risk of an individual patient. Six factors have to be considered, for which spaces are provided to indicate the respective findings or indices that represent the risk categories.
PPD are measured at four sites per tooth (mesiobuccal, buccal, distobuccal, oral). The amount of sites that bleed after probing in % of all measured sites is calculated (1) and the number of sites with PPD ⩾5 mm is counted (2).
The number of missing teeth (except third molars) is counted (3).
Relative bone in % of root length is assessed in posterior teeth (site of most severe destruction). The bone loss-age index is assessed by dividing relative bone loss by patient's actual age (4).
In bite wings an estimation is used: 1 mm = 10% (4).
The patient is asked about current cigarette smoking (number of cigarettes per day). Patients who have quit smoking for a minimum of 5 years are regarded as former smokers (5).
If at least two of the considered six risk indicators and factors indicate a high risk the patient is assigned generally to a high risk.
The respective cell with the definitive risk assessment (low, moderate, high) is marked and the actual periodontal risk score noted in the patient's chart.
PPD, probing pocket depths; BOP, bleeding on probing.

Using these classes for each patient, a prognosis index (number of questionable teeth+number of hopeless teeth/total number of teeth present) was calculated. According to the prognosis index, three categories were created:

- A: prognosis index <0.27;
- B: $0.27 \leqslant$ prognosis index $\leqslant 0.5$;
- C: prognosis index >0.5;

All radiographic assessments were performed by one examiner (B. P.).

Evaluation of patients' charts

Tooth loss during active therapy was assessed by comparing the baseline examination (before active treatment) with the first SPT examination and control of the treatment entries. The main outcome variable of this study (tooth loss after APT) was assessed by comparison of the first SPT examination with the re-examination 10 years $\pm$ 6 months after the initiation of periodontal treatment. According to tooth loss, all patients were assigned to one of three groups (Hirschfeld & Wasserman 1978):

- *well-maintained*: tooth loss 0–3;
- *downhill*: tooth loss 4–9;
- *extreme downhill*: tooth loss ⩾10;

Retrospectively each patient was assigned a baseline diagnosis (e.g. generalized moderate chronic periodontitis) according to the actual classification of periodontal diseases (Armitage 1999). If the information on PAL-V was missing at baseline, this parameter was replaced by interproximal bone loss.

Using the patient chart entries for each patient, the mean values of the gingivitis index (GBI) and plaque index (PCR) documented during SPT were calculated.

It was documented for each patient whether or not he or she had attended SPT at the Section of Periodontology at the University Hospital Heidelberg regularly complying with the intervals that had been recommended. If a patient had extended the recommended SPT interval at least once over 100%, he or she was assigned to the irregular SPT group (e.g. the recommended SPT interval was 6 months and the patient returned for SPT after 13 months).

Using the parameters (BOP index, number of sites with PPD⩾5 mm, number of missing teeth, bone loss index, smoking status, systemic/genetic factors) assessed at the first SPT [first examination after accomplishment of active periodontal treatment (APT)] for each patient the individual periodontitis risk was assessed retrospectively (Table 1) (Ramseier & Lang 1999, Lang & Tonetti 2003). Relative bone loss in percentage of root length was assessed at those posterior teeth exhibiting the most severe destruction. The bone loss-age index was then

Table 2. Quality standards to assess periodontal treatment outcomes (Schweizerische Zahnärzte-Gesellschaft 2000)

Quality standard	Criteria
A+	No probing depth >4 mm
	Minimal bleeding on probing ($<10\%$)
	No visible hard and soft bacterial deposits
	Aesthetically satisfactory periodontal situation
	Absence of pain
	Individually optimal function
A	No persisting pockets >5 mm
	No suppuration
	Occasional bleeding on probing ($\leqslant 25\%$)
	Low plaque index ($\leqslant 30\%$)
	Minimally impaired aesthetics (minimal impaired tooth position or impairment of speech by tooth position or root surfaces visible when speaking)
	Absence of pain
	Satisfactory function
B	Attachment loss with persisting pockets >5 mm
	Suppuration from few persisting pockets
	Bleeding on probing ($>25\%$)
	Insufficient oral hygiene ($>30\%$)
	Adjustable impairment of aesthetics (more than one criterion listed under A present)
	Occasional pain
	Minimally impaired, adjustable function
C	Multiple sites with suppuration
	Recurrent abscesses
	Severely neglected oral hygiene
	Generalized bleeding on probing
	Massive attachment loss without adequate treatment
	Significant attachment loss with pocketing in adolescents
	Incapability to chew due to periodontitis

calculated by dividing relative bone loss by the patient's actual age. For this risk analysis, the results of the IL-1 test obtained at the 10 years $\pm$ 6 months re-examination were used retrospectively. If at least two of the considered six risk indicators and factors indicated a high risk, the patient was generally assigned to a high risk. If at least two factors indicated a moderate risk but not more than one a high risk the patient was generally assigned to the moderate risk group.

Quality standards of treatment outcome

The periodontal status at the time of re-examination was categorized according to the SSO (Swiss Dental Society) criteria (Table 2) (Schweizerische Zahnärzte-Gesellschaft 2000). These quality standards are composite scores that account for clinical parameters (e.g. PPD, BOP, suppuration) and patient-centred outcomes (e.g. absence of pain, aesthetics). A patient was assigned to one of the four standards if at least four criteria of a respective category were present (Table 2).

SPT

SPT encompassed the following elements for all patients at each appointment: Assessment of GBI and PCR, re-instruction and re-motivation to effective individual plaque control, professional tooth cleaning with hand instruments and polishing of all teeth using rubber cups and polishing paste, application of a fluoride gel. Twice a year a dental status and PPD were obtained at four sites per tooth. Thirty seconds after probing, BOP was recorded. Sites exhibiting PPD = 4 mm and BOP as well as sites with PPD $\geqslant$ 5 mm were scaled subgingivally. If a patient exhibited more than five to six sites that ought to be debrided subgingivally, recurrent antiinfective therapy was recommended. From 1992 to 1999 assignment of SPT intervals was not performed according to strict criteria. SPT was rendered to most patients in 3-month intervals during the first year of SPT and later on in 6-month intervals. Patients exhibiting ineffective plaque control (PCR $>$ 35%) or with aggressive periodontitis (at that time: juvenile and rapidly progressive periodontitis) were seen four times a year for SPT (3-month intervals). From October 1999 the assignment of SPT intervals was performed according to the periodontal risk assessment (PRA: Table 1) (Ramseier & Lang 1999, Lang & Tonetti 2003).

Statistical analysis

All data were entered into two data files by two individuals independently. Both data files were compared by subtraction of columns of identical variables. If subtraction resulted in values different from null, the entries were compared with the original charts and corrected.

The patient was looked upon as a statistical unit and tooth loss after APT was defined as the main outcome variable. Quality standards of treatment outcome at re-examination were analysed as the secondary outcome variable (Schweizerische Zahnärzte-Gesellschaft 2000). Descriptive statistics and logistic regression analysis were performed using a computer program (SPSS, Version 12.OG for Windows, SPSS Inc., Chicago, IL, USA). Poisson regressions were modelled by an independent statistician (P. R.) using another program (SAS® version 6.12, SAS Institute, Cary, NC, USA).

Agreement between the results of both laboratories analyzing for IL-1 polymorphism was tested using Cohen's κ.

Using Poisson regression factors should be identified that influenced the dependent variable tooth loss in relation to the number of teeth present at first SPT. Variables assessed at re-examination were entered into the first model [sex, age, diagnosis at initiation of therapy (moderate chronic periodontitis *versus* severe chronic and aggressive periodontitis), IL-1 polymorphism, diabetes mellitus, nicotine consumption (current *versus* never and former 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. Third molars were excluded from analysis.

A further Poisson regression analysis was performed including a prognosis index (Checchi et al. 2002) and the PRA (Lang & Tonetti 2003) at the time point of re-evaluation (first SPT appointment) as independent variables to validate the ability of these prognostic

Table 3. Consecutively recruited patients, non-responders and reasons for non-responding

Total number of qualifying patients that were invited	145
Total number of non-responders	42
Address unknown	13
Deceased	4
Health reasons	5
Personal reasons (living far from Heidelberg, does not care about the study)	9
Appointment not possible	11

Table 4. Patient characteristics

	Total $n = 100$	Non-compliant with SPT $n = 47$	Compliant with SPT $n = 53$
Sex (female)	59	30	29
Age	46.6 ± 10.3	45.5 ± 10.3	47.6 ± 10.3
Smoking			
Current smokers	27	16	11
Former and never smokers	73	31	42
Interleukin-1 polymorphism			
Negative	62	30	32
Positive	38	17	21
Initial diagnosis			
Moderate ChP	30	14	16
Severe ChP/AgP	60/10	28/5	32/5
Teeth	$n = 2301$	$n = 1056$	$n = 1245$

SPT, supportive periodontal treatment; ChP, chronic periodontitis; AgP, aggressive periodontitis.

tools predicting tooth loss. Both prognosis systems were entered as three categories: prognosis index (A, B, C), PRA (0: low risk; 1: moderate risk; 2: high risk) into the analysis. Both the prognosis index and PRA are composite scores. The PRA already accounts explicitly for smoking, diabetes, and IL-1 polymorphism. Thus, these three explanatory variables were not included into the regression model.

Finally a logistic regression analysis was used to identify factors contributing to the quality-of-treatment outcome 10 years after initiation of therapy according to the Swiss quality standards (Schweizerische Zahnärzte-Gesellschaft 2000). For this model, mean PCR was categorized into 10 degrees (0–10%, 11–20%, etc.). Patients' subjective scores of periodontal aesthetics were compared between SPT compliant and non-compliant patients.

Results

Patients

A total of 145 patients had consecutively been invited to participate in the study according to the schedule of therapy initiation 10 years ± 6 months before. Forty-two of these patients were not able or were not willing to be re-examined. Accordingly, the responder rate was 71%. Table 3 lists patients' reasons not to participate in the study. Three further patients had to be excluded during analysis due to incomplete data.

In 63 patients the test for IL-1 polymorphism was analysed using the IAI ParoGen Test, in 47 patients using the GenoType PRT Parodontitis-Risiko-Test. For the 10 patients whose samples were analysed at either laboratory, the agreement was 100% (Cohen's κ 1.0: six patients positive and four negative for both tests).

One hundred patients aged 15–67 years (mean age 46.6 ± 10.3) at initiation of therapy with a total of 2301 teeth at the beginning of SPT participated in the re-examination. Most patients were of Caucasian European origin. Four patients were of Asian origin (two Vietnamese, one Chinese, one Japanese), one patient was of North African heritage (Egyptian). The distribution of patients according to regularity of SPT participation, sex, smoking status, IL-1 polymorphism, and periodontal diagnosis is given in Table 4. Of the total of 100 re-examined patients 59 were females, 53 participated regularly in SPT, and 38 exhibited the IL-1 polymorphism, which approximately represents the prevalence in Central Europe (33%) (De Sanctis & Zucchelli 2000). Seventy patients had been diagnosed with early-onset and severe forms of periodontitis (aggressive or generalized severe chronic periodontitis), 27 were current smokers, which represents the amount of current smokers in the total German population (Statistisches Bundesamt: http://www.destatis.de) (Table 4). Regarding the parameters sex, smoking status, IL-1 polymorphism, and initial diagnosis, analysis failed to reveal statistically significant differences between the groups with regular and irregular SPT, respectively. Using the data from reevaluation (first SPT after accomplishment of active periodontal therapy), 60 patients were assigned to a moderate and 40 to a high individual periodontal risk (Lang & Tonetti 2003).

Tooth loss

In the course of 10 years after initiation of antiinfective therapy the whole patient collective lost 55 teeth during active therapy (antiinfective and surgical periodontal treatment) and 155 further teeth after accomplishment of APT. This represents a mean loss of 2.1 teeth per patient (active therapy: 0.55; SPT: 1.55). According to tooth loss after active therapy 89 patients were classified as ''well maintained'', nine as ''downhill'', and two as ''extreme downhill''. Only one of the patients attending SPT regularly was assigned to the group ''downhill'' (2%) and none to ''extreme downhill''. In the non-compliant group eight patients were classified as ''downhill'' (17%) and two as ''extreme downhill'' (4%).

Excluding the individual periodontal risk at the initiation of SPT Poisson regression analysis identified mean PCR ($p < 0.0001$), regular participation in SPT ($p < 0.0001$), age ($p < 0.0001$), initial diagnosis ($p = 0.0005$), IL-1 polymorphism ($p = 0.0007$), smoking ($p = 0.0053$), and sex ($p = 0.0487$) as factors statistically significantly influencing tooth loss. Whereas regular SPT participation protected against tooth loss, higher PCR, positive test for IL-1 polymorphism, smoking, diagnosis of aggressive or severe chronic periodontitis, female sex, and higher age were associated with increased tooth loss (Table 5). Whereas a 10% increase of PCR was associated with a risk ratio of 1.58, i.e. a 58% increase of the risk for tooth loss, 1 year of age was associated with a 5% increase of the risk for tooth

Table 5. Poisson regression analysis: tooth loss after active periodontal treatment (APT) in relation to retrospective factors

	Estimate	SE	*t*	*P*	Risk ratio
Intercept	− 6.3675	0.7331	− 8.69	< 0.0001	
Irregular SPT	1.1552	0.2287	5.05	< 0.0001	3.1746
Diagnosis (severe ChP/AgP)	0.8484	0.2337	3.63	0.0005	2.3359
Interleukin-1 polymorphism	0.6255	0.1785	3.50	0.0007	1.8692
Smoking	0.5891	0.2063	2.86	0.0053	1.8025
Mean plaque control record (10% step)	0.4571	0.7675	5.96	< 0.0001	1.5795
Sex (female)	0.3747	0.1876	2.00	0.0487	1.4545
Age (1 year)	0.0499	0.0096	5.22	< 0.0001	1.0511
Diabetes mellitus	0.3891	0.3142	1.24	0.2188	1.4757

Dependent variable: tooth loss after APT; $n = 100$.
ChP, chronic periodontitis; AgP, aggressive periodontitis; SPT, supportive periodontal therapy.

Table 6. Tooth loss per patient over 10 years of supportive periodontal treatment (SPT)

	n	Tooth loss		
		mean ± SD	median	range
Total	100	1.55 ± 3.29		0–28
SPT				
Regular	53	0.55 ± 0.99	0	0–5
Irregular	47	2.68 ± 4.44	1	0–28
Interleukin-1 polymorphism				
Negative	62	1.13 ± 1.74	1	0–10
Positive	38	2.24 ± 4.82	1	0–28
Initial diagnosis				
Moderate chronic	30	0.80 ± 1.45	0	0–5
Severe chronic/aggressive	70	1.87 ± 3.78	1	0–28
Sex				
Female	59	1.83 ± 3.98	1	0–28
Male	41	1.15 ± 1.91	0	0–10
Smoking				
Current	27	2.22 ± 5.37	1	0–28
Never and former	73	1.30 ± 2.06	0	0–10

SD, standard deviation.

loss. Means, medians, and ranges of tooth loss per patient after APT according to regular participation in SPT, IL-1 polymorphism, initial diagnosis, sex, and current smoking are given in Table 6.

The 53 patients regularly attending SPT lost 0.55 ± 0.99 teeth per patient within 10 years. Those 47 patients who failed to participate regularly in SPT lost 2.68 ± 4.44 teeth per patient. Thus, without regular SPT the number of teeth lost was nearly fivefold (Table 6). In 38 patients the IL-1-polymorphism was detected. Mean tooth loss per patient in this group was 2.24 ± 4.82, whereas IL-1-negative patients lost 1.13 ± 1.74 teeth (Table 6).

Prognosis

At the first SPT appointment none of the patients was classified to have a low periodontal risk according to the PRA. Thus, only moderate and high risks were entered into the Poisson regression. Poisson regression analysis failed to retain the prognosis index (Checchi et al. 2002) as a statistically significant predictor for tooth loss in the model, whereas a high periodontal risk according to Lang & Tonetti (2003) at the start of SPT was statistically significantly associated with future tooth loss ($p < 0.0001$). Mean PCR during SPT ($p < 0.0001$), irregular SPT ($p < 0.0001$), age ($p < 0.0001$), initial diagnosis ($p = 0.0185$), and sex ($p = 0.0147$) correlated with tooth loss as well (Table 7).

SSO criteria for quality-of-treatment outcome

For analysis classes B and C were fused, because only two patients exhibited class C. Out of all considered factors, logistic regression analysis identified regular SPT and mean PCR during SPT as a statistically significant influence on the quality standard (Table 8). Thirty-four participants regularly attending SPT exhibited a very good periodontal standard (class A) at the time of re-examination, whereas in 19 patients the situation required improvement (class B) (Schweizerische Zahnärzte-Gesellschaft 2000). For those attending SPT irregularly, the number of patients who needed improvement (class B; $n = 37$) was statistically significantly higher than class A patients ($n = 10$; $p = 0.001$).

Patients compliant with regular SPT subjectively rated periodontal aesthetics with better scores than non-compliant patients ($p < 0.001$) (Table 9). Two patients could not be included into analysis of periodontal aesthetics: one patient had lost all teeth (irregular SPT), another patient's data were lost (regular SPT).

Discussion

Patients

For this study all patients, for whom P. E. had initiated systematical periodontal treatment 10 years ± 6 months ago, were recruited consecutively. Not only patients still being treated at the Section of Periodontology were invited, but also patients who had quit treatment there due to various reasons (e.g. moving, continuation of therapy at other dentists). A total of 145 patients were invited consecutively according to the sequence of treatment initiation. Forty-two of these were not able or willing to participate, resulting in a responder rate of 71%. Three patients had to be excluded due to incomplete data.

Originally in most samples 3-month SPT intervals were intended. However, retrospective analysis revealed that this rhythm was not kept consequently: Wood et al. reported an average SPT interval of 6 months and less in 30.2% of patients. In 47.6% patients kept intervals between 6 and 9 months and in 22.2% of 9 months or more (Wood et al. 1989). Checchi and colleagues calculated patient compliance as mean of the number of SPT appointments per year. Patients who complied with the recommended rhythm (three to four per year) were classified as compliant ($n = 23$), for SPT interval mean values below the recommended number of patients were assessed as non-compliant ($n = 69$) (Checchi et al. 2002). In this

Table 7. Poisson regression analysis: tooth loss after active periodontal therapy (APT) in relation to prognostic and risk parameters

	Estimate	SE	*t*	*p*	Risk ratio
Constant	− 5.3612	0.6054	− 8.86	< 0.0001	
Irregular SPT	1.2881	0.2256	5.71	< 0.0001	3.6258
High periodontal risk at start of SPT (Lang & Tonetti 2003)	0.9838	0.1915	5.14	< 0.0001	2.6745
Diagnosis (severe ChP/AgP)	0.6106	0.2546	2.40	0.0185	1.8412
Sex (female)	0.4590	0.1845	2.49	0.0147	1.5824
Mean plaque control record (10% step)	0.4108	0.8014	5.13	< 0.0001	1.5080
Age (1 year)	0.0381	0.0079	4.81	< 0.0001	1.0388
Prognosis A	0.1998	0.2514	0.79	0.4289	1.2211
Index B (Checchi et al. 2002)	− 0.0505	0.2958	− 0.17	0.8649	0.9508

Dependent variable: tooth loss after APT; $n = 100$.
SPT, supportive periodontal treatment.

Table 8. Logistic regression analysis: quality of periodontal treatment outcome (SSO quality standard A or B/C; Schweizerische Zahnärzte-Gesellschaft 2000) 10 years after initiation of periodontal therapy

Variable	Regression coefficient	Standard error	Odds ratio	*p*
Constant	− 0.827	1.814	0.437	0.648
Irregular SPT	1.551	0.497	4.715	0.002
Mean plaque control record (10% steps)	0.727	0.286	2.069	0.011
Age	− 0.042	0.028	0.959	0.129
Diagnosis (severe ChP/AgP)	0.867	0.582	2.381	0.136
Tooth loss during active therapy	0.202	0.293	1.224	0.491
Smoking	0.328	0.592	1.389	0.579
Sex	− 0.243	0.514	0.784	0.636
Interleukin-1 polymorphism	0.212	0.520	1.237	0.683
Prognosis index (Checchi et al. 2002)	− 0.188	0.527	0.829	0.722

Table 9. Patients' subjective ratings of periodontal aesthetics at re-examination

Score	Non-compliant with SPT $n = 46$	Compliant with SPT $n = 52$
Excellent	9	29
Good	23	23
Satisfactory	11	0
Fair	3	0
Poor	0	0

SPT, supportive periodontal treatment.

study another definition for compliant (regular SPT) and non-compliant (irregular SPT) was chosen: patients regularly attending SPT at the Section of Periodontology at the University Hospital of Heidelberg and maintaining the recommended intervals were judged as compliant. If a patient had extended the recommended SPT interval at least once over 100% he or she was assigned to the non-compliant or irregular SPT group (e.g. the recommended SPT interval is 6 months and the patient returns for SPT after 13 months). A patient who had quit SPT provided by periodontal specialists may have attended a kind of maintenance care with his or her family dentist. Our analysis only considers compliance with the specialist-based SPT rendered at the Section of Periodontology. Both groups (compliant/non-compliant) failed to exhibit statistically significant differences regarding age, smoking, IL-1 polymorphism, and initial diagnosis.

Tooth loss

For this analysis tooth loss was chosen as the main outcome variable. Although patient charts were searched for and all participants of this study were asked about them, the causes of extractions could not be revealed, particularly for teeth that had been removed alio loco. This is a potential problem of studies including patients who have quit regular SPT. The information on the influence of regular/irregular SPT is gained. However, it becomes more difficult and sometimes impossible to collect information on reasons of extraction. Carnevale et al. (2007b) who reported on a frequent SPT sample saw root fractures as the most frequent reason for extraction, followed by periodontal reasons (Carnevale et al. 2007b).

Patients who suffered from aggressive or moderate to severe chronic periodontitis and were re-examined in this study lost a total of 155 teeth during 10 years after active periodontal treatment, i.e. a mean loss of 1.55 teeth per patient or 0.155 teeth per patient and year, respectively. Thus, tooth loss occurred quite rarely. A comparison with other retrospective studies is difficult because they report partially longer and more heterogeneous observation periods (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Carnevale et al. 2007a, b). Furthermore, in most retrospective studies only patients were re-examined who stayed in SPT for the whole observation period (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Fardal et al. 2004, Carnevale et al. 2007a, b). A meaningful comparison of those studies can be drawn with the compliant subgroup of this study. Mean tooth loss per patient in the regular SPT subgroup was 0.55 per patient and 0.055 per patient and year, respectively. All patients bar one in this subgroup were classified as well maintained according to Hirschfeld & Wasserman (1978). This rate of tooth loss is similar to that reported in other samples with regular SPT: 0.066 (König et al. 2001) and 0.036 (Fardal et al. 2004). Carnevale et al. (2007b) report a slightly smaller mean rate of annual tooth loss: 0.02. However, this group extracted 576 teeth during active treatment, which corresponds to a mean tooth loss per patient of 2.1 during the whole treatment period compared with 1.0 in this study (Carnevale et al. 2007b). By extracting more questionable teeth during active treatment, the risk of tooth loss during SPT is likely to be reduced. Over all, the observation confirms that

attachment loss (Joss et al. 1994, Kaldahl et al. 1996), recurrence of pockets (Carnevale et al. 2007a), and tooth loss (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Tonetti et al. 2000, König et al. 2001, Checchi et al. 2002, Fardal et al. 2004, Muzzi et al. 2006, Faggion et al. 2007, Carnevale et al. 2007b) occur rarely in patients regularly attending SPT. Patients attending SPT irregularly lost a mean of 2.68 teeth per patient, i.e. almost five times more teeth during the same observation period than regular SPT patients. After adjustment for other risk factors, the risk ratio still is 3.17 (Table 5). Thus, regular SPT provided by a periodontal specialist is an effective tool to prevent tooth loss in periodontitis patients. This confirms findings of other authors who observed better periodontal stability in patients attending specialist-based SPT compared with maintenance provided by the family dentist (Cortellini & Tonetti 2004, Fardal 2006).

However, which further factors influence tooth loss after active periodontal treatment? Using a Poisson regression analysis it was attempted to identify factors associated with tooth loss during SPT at the patient level [sex, age, baseline diagnosis (moderate chronic *versus* severe chronic and aggressive periodontitis), IL-1 polymorphism, smoking, prognosis index, mean PCR during SPT, compliance of participation in SPT]. Irregular participation in SPT was identified as the strongest influence associated with tooth loss.

The present study identified the mean of the PCR scores recorded during SPT to be a strong factor correlating with tooth loss, i.e. the higher the PCR scores during SPT, the higher the risk for tooth loss. Carnevale et al. (2007b) identified full-mouth plaque scores (FMPS) at the last SPT appointment to statistically significantly decrease the risk for tooth loss (Carnevale et al. 2007b). At first glance this seems paradoxical. We expect tooth loss to be associated with periodontal infection that is at least partially correlated with supragingival plaque, i.e. FMPS. The inverse association may be explained by the fact that FMPS of the last appointment is less relevant than those of earlier appointments. Considering this fact in the present study, the mean PCR of all SPT appointments was calculated for each patient to characterize an individual's average plaque control. FMPS is described as follows: dental plaque is dichotomously evaluated at four sites per tooth. Then the amount of sites with plaque in relation to all recorded sites is given in per cent (Carnevale et al. 2007a). The PCR (O'Leary et al. 1972) records plaque at the dentogingival junction at four sites per tooth and gives the amount of sites with plaque in relation to all recorded sites in per cent. Thus, both scoring systems are likely to render similar results. A difficulty with this approach is that we could only use the PCR values recorded during the time the patients attended specialist-based SPT at the Section of Periodontology. It may be speculated that patients who quit regular SPT had higher PCR scores while having no or general dentist's SPT. However, the information on individual plaque control beyond regular SPT was not available, which may be considered as another disadvantage of including patients who have quit regular SPT.

Presence of IL-1 polymorphism was identified as a factor associated statistically significantly with tooth loss during SPT. The significance of the IL-1 genotype in pathogenesis and progression of periodontitis is controversial (Huynh-Ba et al. 2007). Whereas a significantly increased risk for tooth loss was observed over a period of 5–16 years in a SPT sample (McGuire & Nunn 1999), within an observation period of 2 years after non-surgical periodontal therapy another study failed to observe an influence of this genotype on attachment loss (Ehmke et al. 1999). Two years of observation in a SPT sample is clearly too short to detect differences between genotype positive and negative individuals. Investigating stability after regenerative therapy of infrabony defects, similar attachment gains were observed 1 year after therapy. Statistically significant differences between genotype positive and negative patients were observed 3 years later, i.e. 4 years after therapy (De Sanctis & Zucchelli 2000). Besides the time of observation, the parameter to assess the influence of the IL-1 polymorphism is another issue. The surrogate parameter ''attachment loss'' (Ehmke et al. 1999) is a less-relevant end point than the true clinical end point ''tooth loss'' that was detected by McGuire & Nunn (1999) and in this study. Other studies using the true end point tooth loss did not consider the IL-1 polymorphism (Faggion et al. 2007) or although considering it could not detect a significant effect on tooth loss (Muzzi et al. 2006). However, Muzzi and colleagues included only 60 patients in their analysis who all participated regularly in SPT. Their sample size might be too small to detect the influence of the IL-1 genotype. Furthermore, regular SPT may have obscured its effect (Muzzi et al. 2006).

Initial diagnosis was also identified as a statistically significant influence on tooth loss. For aggressive and generalized severe chronic periodontitis, risk for tooth loss was doubled compared with moderate periodontitis. Carnevale et al. (2007b) used another classification and failed to find a correlation between disease severity and tooth loss during SPT (Carnevale et al. 2007b). Current smoking (McGuire & Nunn 1996, Chambrone & Chambrone 2006, Dannewitz et al. 2006, Leung et al. 2006) and age (Chambrone & Chambrone 2006, Leung et al. 2006) were confirmed to attribute to the risk of tooth loss.

An established periodontal risk factor, which failed to be associated with tooth loss in the present study, diabetes mellitus, was significantly associated with increased tooth loss in another study, which did not consider the IL-1 genotype (Faggion et al. 2007). It is known that diabetes is associated with more severe periodontitis under otherwise similar conditions (Emrich et al. 1991). However, control and duration of diabetes also play a role (Seppälä et al. 1993). Neither Faggion et al. (2007) nor this analysis did account for these coparameters.

It has to be kept in mind that many of the 155 teeth were lost after patients had quit treatment at the Section of Periodontology. In many cases it could not be clarified why teeth were removed alio loco. Rarely teeth are lost spontaneously or exclusively because of disease. In most cases the decision of a dentist leads to extraction. Beyond the judgment of periodontal or general oral health, other criteria play an important role in the extraction of teeth: prosthetic constructive considerations, the individual dentist's treatment philosophy, and the attitude of the individual patient regarding his or her teeth (Zaher et al. 2005). These difficult-to-control conditions do not simplify the interpretation of the true clinical end point ''tooth loss'' (Hujoel et al. 1999). Furthermore, beyond parameters on the patient level, tooth-specific parameters are likely to influence tooth-loss. Thus, we did not expect

to be able to explain tooth loss by periodontal and host response parameters on a patient level alone (Faggion et al. 2007).

Prognosis

Already Hirschfeld & Wasserman (1978) attempted to assign a prognosis to treated teeth in advance. They distinguished between favorable and questionable prognosis. A questionable prognosis was assigned to a tooth if it showed one or more of the following criteria: (i) furcation involvement, (ii) deep noneradicable pocket, (iii) extensive alveolar bone loss, (iv) marked mobility in conjunction with pocket depth (two or 2.5 on a scale of 3) (Hirschfeld & Wasserman 1978, McFall 1982). These criteria are not precisely defined and leave large latitude of judgment. The rate of tooth loss of such questionable teeth without furcation involvement was 30% compared with 8% considering all teeth. However, the rate of tooth loss varied from 12% in the well-maintained subgroup, over 55% in the downhill, to 92% in the extreme downhill subgroup (Hirschfeld & Wasserman 1978). Hirschfeld & Wasserman considered only tooth-related factors for their prognosis. Patient-related factors such as sex, age or smoking were not incorporated. However, evidently patient-related and other tooth-related factors played an important role for tooth loss. The prognostic system of Hirschfeld & Wasserman (1978) does not suit treatment planning, particularly when prosthodontic reconstruction is required.

Interestingly the prognosis index according to Checchi et al. (2002) was not useful to predict tooth loss in the investigated sample. A Poisson regression analysis incorporating independent variables, as e.g. regular/irregular SPT participation, revealed a statistically significant association of high periodontal risk at the start of SPT according to the PRA (Lang & Tonetti 2003) with tooth loss, whereas the prognosis index according to Checchi et al. failed to show any correlation (Checchi et al. 2002). Hence, for the first time, this study provides evidence that patients assigned to the high-risk group according to the Lang & Tonetti risk assessment (Lang & Tonetti 2003) after accomplishment of APT suffer from a higher rate of tooth loss than the other risk groups.

SSO quality criteria

If the SSO criteria are used to judge the long-term success of periodontal treatment, regular SPT and effective oral hygiene (i.e. low PCR scores) are the only significant factors explaining the dependent variable (Table 8). All patients received APT from the same trained periodontist (P. E.) according to a comprehensive treatment rationale. Regardless of age, sex, or initial diagnosis, individual oral hygiene and regular SPT significantly influenced the outcome 10 years after periodontal therapy exclusively.

Conclusions

- In patients after systematic periodontal treatment, regular SPT and effective oral hygiene (low PCR) are effective tools to

(i) prevent tooth loss and
(ii) maintain a beneficial outcome on a long-term basis.

- After accomplishment of active periodontal therapy IL-1 polymorphism, ineffective plaque control, irregular supportive periodontal treatment, initial diagnosis, smoking, age and sex increase the risk for tooth loss.
- Patients assigned to the high-risk group according to the Lang & Tonetti risk assessment (PRA: Lang & Tonetti 2003) after accomplishment of APT suffer from a higher rate of tooth loss than the other risk groups.

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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. In periodontal diseased teeth prognosis of tooth loss is still difficult. This study aims to identify prognostic factors.

Principal findings: The following factors increase the risk for tooth: ineffective oral hygiene, irregular SPT, IL-1 polymorphism, initial diagnosis, smoking, age and female sex.

Practical implications: Regular supportive periodontal therapy and effective plaque control are the most effective tools to prevent tooth loss and maintain a favourable periodontal status. Assessment of IL-1 polymorphism contributes to the individual periodontal risk profile.