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Significance of Periodontal Risk Assessment in the recurrence of periodontitis and tooth loss

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Abstract

Aim: To investigate the association of the Periodontal Risk Assessment (PRA) model categories with periodontitis recurrence and tooth loss during supportive periodontal therapy (SPT) and to explore the role of patient compliance.

Material and Methods: In a retrospective cohort, PRA was performed for 160 patients after active periodontal therapy (APT) and after 9.5 ± 4.5 years of SPT. The recurrence of periodontitis and tooth loss were analysed according to the patient's risk profile (low, moderate or high) after APT and compliance with SPT. The association of risk factors with tooth loss and recurrence of periodontitis was investigated using logistic regression analysis.

Results: In 18.2% of patients with a low-risk profile, in 42.2% of patients with a moderate-risk profile and in 49.2% of patients with a high-risk profile after APT, periodontitis recurred. During SPT, 1.61 ± 2.8 teeth/patient were lost. High-risk profile patients lost significantly more teeth (2.59 ± 3.9) than patients with moderate- (1.02 ± 1.8) or low-risk profiles (1.18 ± 1.9) (Kruskal–Wallis test, $p = 0.0229$). Patients with erratic compliance lost significantly (Kruskal–Wallis test, $p = 0.0067$) more teeth (3.11 ± 4.5) than patients compliant with SPT (1.07 ± 1.6).

Conclusions: In multivariate logistic regression analysis, a high-risk patient profile according to the PRA model at the end of APT was associated with recurrence of periodontitis. Another significant factor for recurrence of periodontitis was an SPT duration of more than 10 years.

Key words: compliance; maintenance care; periodontitis; progression; recurrence; risk factors; SPT; supportive periodontal therapy; tooth loss

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Following active periodontal therapy (APT), individualized supportive periodontal therapy (SPT) is usually initiated in order to prevent recurrence of disease. As treated patients are not equally susceptible to periodontal disease progression (Rosling et al. 2001), some patients may have to be offered supporting periodontal therapy (SPT) at shorter intervals than less susceptible patients. Generally, it has been attempted to establish recall appointments every 3–4 months to maintain treatment outcomes following APT in highly susceptible patients (e.g. Knowles et al. 1979, Lindhe & Nyman 1984). On the other hand, patients treated for chronic periodontitis, but with less susceptibility to recurrence of disease, may be served with one appointment a year that would suffice to keep the periodontal treatment outcomes stable. Hence, identification of individuals who are at a high risk for disease progression after APT represents a real challenge for the clinician. The determination of the individual needs of periodontitis patients and the performance of SPT at regular intervals that are adequate are of critical importance to prevent disease recurrence and possibly tooth loss.

Because chronic periodontitis represents a multi-factorial opportunistic infection (Socransky & Haffajee 1992), known or putative risk factors should be evaluated concomitantly in order to identify the susceptibility of patients for periodontitis recurrence. The creation of multi-factorial risk assessment

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models including relevant risk factors for future disease progression was already highlighted decades ago (Beck 1994). More recently, a Periodontal Risk Assessment (PRA) using six parameters to evaluate the risk for recurrence of periodontitis at a patient level was proposed for clinical use (Lang & Tonetti 2003). This functional diagram includes (1) full-mouth bleeding on probing (BOP) percentages, (2) the number of residual pockets of 5 mm or greater, (3) the number of teeth lost deducted from a total of 28 teeth, (4) the percentage of loss of periodontal support (bone) in the worst posterior sites in relation to patient's age, (5) systemic and/or genetic conditions and (6) environmental factors such as the smoking status. These factors are evaluated after active periodontal therapy. They should facilitate the classification of the patients into a low, moderate or highly susceptible patient group for disease recurrence. To date, only a few longitudinal studies have attempted to validate the effect and reproducibility of this approach (Persson et al. 2003, Jansson & Norderyd 2008).

In a 4-year prospective cohort study (Persson et al. 2003), complete periodontal stability after individually tailored recall intervals according to the PRA could be demonstrated in a subgroup of patients with a negative interleukin-1 (IL-1) polymorphism. On the other hand, patients with a positive iIL-1 polymorphism yielded slightly deteriorated periodontal conditions, indicating that the PRA did not adequately predict disease recurrence or periodontal stability in a small proportion of treated periodontitis patients.

A validation of the PRA model arose from a recent study with 100 patients treated for periodontitis and then maintained for 10 years $\pm$ 6 month (Eickholz et al. 2008). In this study, it was demonstrated that patients assigned to the high-risk category for disease progression after successful APT had a higher rate of tooth loss than the remainder of the patients belonging to the moderate- or low-risk group.

A recent study evaluated the PRA model as well (Jansson & Norderyd 2008). The authors included a limited number of patients ($n = 20$) treated for severe periodontitis and concluded that the proposed model overestimated the risk for disease progression.

Even though intervals and extent of SPT may have been suggested to periodontal patients after APT, it has been well documented that patients may or may not at all comply with the suggested maintenance regimes (Wilson Jr. et al. 1984, Checchi et al. 1994, Demetriou et al. 1995, Soolari & Rokn 2003). In these private practice patient studies, a very small group (3.3%, 16%, 27.4% and 30%, respectively) of the patients complied with the recommended SPT intervals. Approximately half of the patients (57.6% and 49%) yielded erratic compliance and one-third of the patients (39.1% and 34%) never returned for SPT. In a recent study of only 12-month duration (Lorentz et al. 2009), 60% of patients were compliers, 15.2% were erratic compliers and 24.8% never returned for the maintenance visits.

Hence, in addition to the susceptibility for recurrence of the disease, the compliance with the suggested SPT influenced the outcomes.

The aims of this retrospective longitudinal study were:

- to assess the association of the proposed PRA model with disease progression and tooth loss,
- to assess the association of compliance with proposed SPT on disease progression and tooth loss.

Material and Methods

In this retrospective cohort study, patients with chronic periodontitis were treated by graduate students as a part of their educational training at the Department of Periodontology and Fixed Prosthodontics, University of Berne, during the period 1978–2002. Details of the treatment protocol and the SPT provided have been described recently (Matuliene et al. 2008).

In the present analysis, data of 160 treated patients in SPT presented in the study mentioned (Matuliene et al. 2008) are documented. Out of the original cohort of 172 patients, 12 patients could not be included in the present analysis owing to the fact that data on BOP of these patients were missing.

In essence, at baseline (T0), i.e. before starting active periodontal therapy, complete clinical periodontal and radiographic examinations for 88 (55%) females and 72 (45%) males, between 15 and 71 years of age (mean: 46.7; SD 10.9 years), were performed.

According to the definition of a periodontal case proposed at the 5th European Workshop on Periodontology (2005) (Tonetti & Claffey 2005), all patients fulfilled the criteria for Level 1 periodontitis (presence of proximal attachment loss of $\geqslant 3$ mm in $\geqslant 2$ non-adjacent teeth). Of these, 88.1% (141) presented with a Level 2 periodontitis (presence of proximal attachment loss of $\geqslant 5$ mm in $\geqslant 30\%$ of the teeth present). Patients were then treated according to a comprehensive periodontal treatment plan (Lang & Löe 1993). All examinations were repeated at the completion of active treatment (APT), i.e. before the patients were included in a strictly organized maintenance system (T1). Following completion of APT, patients were encouraged to attend the SPT programme either at University of Berne or they were referred back to private practitioners for SPT. Until 1997, all patients were recalled every 3–6 months (Knowles et al. 1979). After 1997, the frequency of the maintenance visits was tailored to the needs of the patients according to the criteria of the PRA model, which was introduced at the University at that time. All 160 patients of the present study were then scheduled according to their individual PRA.

The third and last complete clinical periodontal and radiographic examinations (T2) were performed after a mean SPT of 9.5 years (SD 4.5 years). The mean patient age at this re-evaluation was 56.2 years (SD 11.4 years).

PRA

On the basis of the patient data at the end of APT (T1), the risk for periodontal disease progression and recurrence was calculated retrospectively using the multi-factorial PRA model (Lang & Tonetti 2003). Risk assessment was, again, performed at re-evaluation (T2).

In brief, the PRA included the following parameters:

1. The percentage of sites with bleeding on probing.
2. The number of residual sites with probing pocket depth (PPD) $\geqslant 5$ mm.
3. The number of teeth lost from a total of 28 teeth.
4. The percentage loss of radiographic periodontal support (Schei et al. 1959) in the worst posterior region in relation to the patient's age.

5. Presence of systemic factors (e.g. data only for self-reported Diabetes mellitus (Type 2). However, the composite IL-1 genotype was unknown).
6. Environmental factors such as categories of self-reported cigarette smoking.

The composite evaluation of the PRA has been presented previously (Lang & Tonetti 2003). A summary of the definitions of low-, moderate- and high-risk categories for disease progression is presented in Table 1.

For the purpose of tailoring the SPT visits to the individual needs of the patients, three patient *risk profiles* were defined:

Patients displaying a *low-risk profile* for periodontitis recurrence yield all risk factors in the low-risk category or, at most, one risk factor in the moderate-risk category. For such patients, an SPT interval of at least once a year was recommended.

Patients presenting with at least two risk factors in the moderate-risk category and at most one risk factor in the high-risk category were classified as displaying a *moderate-risk profile* and needed SPT twice a year.

Lastly, patients showing at least two risk factors in the high-risk category are defined to belong to a *high-risk profile* for disease recurrence. They were recommended to appear for SPT at intervals of 3–4 months per year.

Compliance

According to the criteria specified by Demirel & Efeodlu (1995), patients were considered as ''compliers'' if they presented reliably and consistently for the SPT visits and complied completely with the proposed intervals during the entire duration of SPT. Patients who missed any of the suggested maintenance visits, but continued to appear irregularly were identified as ''erratic compliers''.

Patients not complying with the suggested SPT and abstaining from maintenance visits were designated as ''non-compliers''. Such patients were not available for re-evaluation, and hence are not considered in the present analysis.

Progression of periodontal disease

In the 5th European Workshop on Periodontology (2005) (Tonetti & Claffey 2005), a periodontitis case was defined as being *progressive* if there were at least two teeth with $\geqslant 3$ mm proximal attachment loss between two observation points. In the present study, this definition was adapted to define recurrence of periodontitis between the end of APT (T1) and re-evaluation (T2).

Data management and statistical analysis

Data were entered in a computer database and corrected for implausible entries. In this study, the patient was the unit of analysis. When comparing the numeric characteristics between patients categorized into the low-, moderate- and high-risk profile groups, non-parametric Kruskal–Wallis test statistics were calculated to test the hypothesis of no difference between the three groups. This test is an extension of more than two groups of Wilcoxon's rank-sum test for the comparison of two groups.

To quantify the association of patient-level risk factors with tooth loss or recurrence of periodontitis, univariable and multivariable logistic regression analyses with odds ratios (OR) and 95% confidence intervals (95% CI) were applied and reported. Appropriately constructed indicator variables were entered to compare the moderate- and high-risk profile patients with patients with a low-risk profile. When entering continuous variables into the logistic regression analysis, the reported ORs reflect the increase in the odds of the outcome per one unit increase in the variable and the unit is indicated in the results table. Two-sided *p*-values were assessed and statistical significance was declared for *p*-values lower than 0.05. All analyses were conducted using Stata® version 10.1 (StataCorp., College Station, TX, USA).

Table 1. Periodontal risk assessment for patients in supportive periodontal therapy (SPT) according to Lang & Tonetti (2003)

Risk profile	BOP (%)	PD $\geqslant$ 5 mm	Tooth loss	BL/age	Systemic/ generic	Environmental
Low	$\leqslant 9$	$\leqslant 4$	$\leqslant 4$	<0.5	No	NS, FS
Moderate	10–25	5–8	5–8	0.5–1	No	10–19 cigarettes/day
High	$\geqslant 26$	$\geqslant 9$	$\geqslant 9$	>1	Yes	$\geqslant 20$ cigarettes/day

BOP, bleeding on probing; BL, baseline; PD, pocket depth; NS, never smokers; FS, former smokers.

Results

SPT

After APT, 93 (58.1%) patients attended the SPT programme at the University of Berne according to their individual needs revealed by the PRA. The other 67 (41.9%) patients had been referred back to their private practitioner for SPT with suggestions to the colleagues of intervals between visits according to the PRA. The frequencies for SPT at the University and in private practice have been published previously (Matuliene et al. 2008).

PRA and compliance

Eleven patients (6.9%) with a low-risk profile, 90 patients (56.2%) with a moderate-risk profile and 59 patients (36.9%) with a high-risk profile after APT (T1) were identified. All patients with a low-risk profile for the recurrence of periodontitis were *compliers*, e.g. attended the SPT visits at least once a year. In the moderate-risk profile group, 15.5% (14) of the patients, and in the high-risk profile group, 47.5% (28) of the patients were *erratic compliers* (Table 2).

Tooth loss

During APT, 278 teeth from a total of 3849 were lost (7.2%). Additionally, 258 teeth from a total of 3571 present at T1 (7.2%) were lost during the observation period of 9.5 years (SD 4.5 years) (1.61 teeth/patient, SD 2.83). Seventy-nine patients (49.4%) kept all their teeth. Thirty patients (18.7%) lost one tooth, 20 patients (12.5%) lost two teeth, 10 patients (6.3%) lost three teeth and 21 patients (13.1%) lost four teeth or more (Table 3).

The tooth loss was analysed according to the patient *compliance* with SPT. After APT, *compliant* patients had 22.7 teeth (SD 3.96 teeth), whereas *erratic compliers* presented with 21.3 teeth (SD 4.82 teeth)

75.4% of *compliant* patients had experienced no tooth loss or lost only one tooth in comparison with 47.6% of

Table 2. Patient's compliance with suggested recall interval and change of periodontal risk during the observation period (decreased: lower PRA than at T1; increased: higher PRA than at T1)

Patients with a risk profile at T1 (*n*)	Recall interval*	Percentage and numbers of patients (*n*)	Risk profile at T2 Percentage and numbers of patients who showed a change in their risk profile from T1		
			decreased risk profile	no change	increased risk profile
Low/11	< 1/year	0	NA	0	0
	1/year	**27.3% (3)**		**33.3% (1)**	**66.7% (2)**
	2/year	54.5% (6)		33.3% (2)	66.7% (4)
	3–4/year	18.2% (2)		0	100% (2)
	Total	100% (11)			
Moderate/90	< 1/year	2.2% (2)	0	100% (2)	0
	1/year	13.3% (12)	0	58.3% (7)	41.7% (5)
	2/year	**57.8% (52)**	**5.8% (3)**	**75% (39)**	**19.2% (10)**
	3–4/year	26.7% (24)	0	83.3% (20)	16.7% (4)
	Total	100% (90)			
High/59	< 1/year	5.1% (3)	0	100% (3)	NA
	1/year	5.1% (3)	33.3% (1)	66.7% (2)	
	2/year	37.3% (22)	36.4% (8)	63.6% (14)	
	3–4/year	**52.5% (31)**	**32.3% (10)**	**67.7% (21)**	
	Total	100% (59)			

*Bold recommended SPT visit intervals according to PRA (Lang & Tonetti 2003)

PRA, Periodontal Risk Assessment; NA, no percentage available as no patients were in this group.

Table 3. Patient proportions (%) with various tooth losses stratified according to compliance with SPT and the risk profile at T1

No. of teeth lost	0	1	2	3	4	5	6	7	8	9	10	12	14	16	Total % (no. of patients)
% of patients	49.38	18.75	12.50	6.25	2.50	3.13	1.88	1.25	0.63	0.63	0.63	0.63	0.63	1.25	100 (160)
Patient compliance															
Fully	53.39	22.03	9.32	5.93	2.54	3.39	1.69	1.69	0	0	0	0	0	0	100 (118)
Erratic	38.10	9.52	21.43	7.14	2.38	2.38	2.38	0	2.38	2.38	2.38	2.38	2.38	4.76	100 (42)
Risk profile at T1															
Low	54.55	18.18	9.09	9.09	0	0	9.09	0	0	0	0	0	0	0	100 (11)
Moderate	55.56	20.00	12.22	5.56	2.22	2.22	0	0	0	1.11	1.11	0	0	0	100 (90)
High	38.98	16.95	13.56	6.78	3.39	5.08	3.39	3.39	1.69	0	0	1.69	1.69	3.39	100 (59)

SPT, supportive periodontal therapy.

the *erratic compliers*. *Compliant* patients lost at most seven teeth, whereas patients with *erratic compliance* lost up to 16 teeth (Table 3).

During the SPT, *compliant* patients lost 127 teeth from a total of 2677 teeth present at T1 (4.7%), and the patients with *erratic compliance* lost 131 from a total of 894 teeth (14.7%), respectively.

Patients with *erratic compliance* lost statistically significantly (Kruskal–Wallis test, $p = 0.0067$) more teeth (3.12 teeth/patient; SD 4.51 teeth/patient) than *compliant* patients (1.08 teeth/patient; SD 1.64 teeth/patient) (Table 4). The probability of losing a tooth during SPT was not significantly different between *compliant* patients and patients with *erratic compliance* with OR = 1.86; 95% CI 0.91–3.82). Similarly, tooth loss was analysed according to *the risk profile* at T1. After APT, patients with a low-risk profile had 26.1 teeth (SD 2.55 teeth), while patients with a moderate-risk profile presented with 22.6 teeth (SD 4.05 teeth). Patients with a high-risk profile, yielded 21.2 teeth (SD 4.33 teeth).

The patients with a low-risk profile after APT lost 13 teeth during the SPT from a total of 287 teeth present at T1 (4.5%), the patients with a moderate-risk profile lost 92 from 2034 (4.5%) and the patients with a high-risk profile lost 153 from 1250 teeth (12.2%), respectively.

No tooth loss or only the loss of one tooth was observed in 56% of patients with a high-risk profile in comparison with patients with a moderate- or low-risk profile, where 75.6% and 72.7% of patients, respectively, lost at the most one tooth (Table 3). Patients with a high-risk profile after APT lost significantly more teeth (2.59 ± 3.88 teeth/patient) than patients with a moderate- (1.02 teeth/patient; SD 1.76 teeth/patient) or a low-risk profile (1.18; SD 1.89 teeth/patient) (Kruskal–Wallis test, $p = 0.0229$). However, the probability for patients with a low-risk profile of losing any tooth during the SPT was not statistically significantly different from the probability in patients with a moderate-risk profile (OR = 0.96; 95% CI 0.27–3.38) as well as that in patients with a high-risk profile (OR = 1.88; 95% CI 0.51–6.87). If patient compliance with SPT and periodontal risk profile are combined, patients with a high-risk profile at T1 and *erratic compliance* with SPT lost the most teeth (3.6 teeth/patient; SD 5.02) (Table 4). *Compliant* patients with both a moderate- and a high-risk profile after APT lost fewer teeth than patients with *erratic compliance* (0.8 teeth/patient; SD 1.25 teeth/patient *versus* 2.2 teeth/patient; SD 3.21 teeth/patient and 1.7 teeth/patient;

Table 4. Tooth loss (per patient ± SD) stratified according to the risk profile after APT and the compliance with SPT suggestions

Risk profile at T1	Compliance		Not accounted for compliance
	Full	Erratic	
Low	1.18 ± 1.89	NA	1.18 ± 1.89
Moderate	0.80 ± 1.25	2.21 ± 3.21*	1.02 ± 1.76
High	1.71 ± 2.18	3.57 ± 5.02†	2.59 ± 3.88‡
Not accounted for risk	1.08 ± 1.64	3.12 ± 4.51§	

*Kruskal–Wallis test, $p = 0.051$.
†Kruskal–Wallis test, $p = 0.3338$.
‡Kruskal–Wallis test, $p = 0.0229$.
§Kruskal–Wallis test, $p = 0.0067$.
APT, active periodontal therapy; NA, no percentage available as no patients were in this group (see Table 2); SPT, supportive periodontal therapy.

Table 5. Percentage of patients with recurrent periodontitis during SPT according to the risk profile after APT (T1) and the compliance with SPT (the parenthesis include the number of patients experiencing recurrent periodontitis)

Risk profile at T1	Compliance with SPT		Not accounted for compliance
	Full ($n = 118$)	Erratic ($n = 42$)	
Low	18.18 (2)	NA	18.18 (2)
Moderate	42.11 (32)	42.86 (6)	42.22 (38)
High	54.84 (17)	42.86 (12)	49.15 (29)
Total percentage patients with recurrent perioodontitis	43.22 (51)	42.86 (18)	43.13 (69)

APT, active periodontal therapy; SPT, supportive periodontal therapy; NA, no percentage available as no patients were in this group (see Table 2).

SD 2.18 teeth/patient *versus* 3.6 teeth/patient; SD 5.02 teeth/patient, respectively). Although this difference barely reached statistical significance ($p = 0.0511$) in the patients with a moderate-risk profile, it was not statistically significant in the patients with a high-risk profile ($p = 0.3338$).

Progression of periodontitis

According to the definition chosen for recurrence of periodontitis [$\geqslant 2$ teeth with $\geqslant 3$ mm proximal attachment loss between the end of APT (T1) and re-evaluation (T2)], 43.1% (69) of the patients had to be classified as *progressive cases*. Recurrence of periodontitis was observed in similar proportions for *compliant* patients (43.2%) and patients with *erratic compliance* (42.9%). Recurrent periodontitis occurred in 18.2% of patients with a low-risk profile after APT, in 42.2% of patients with a moderate-risk profile and in 49.2% of patients with a high-risk profile (Table 5).

Multivariate models

To analyse the putative risk factors for *tooth loss*, *more than one tooth loss* and for *recurrence of periodontits*, two multivariate regression analyses models were performed.

The first included the following parameters: gender, age, years of SPT, periodontal risk profile after APT and patient compliance with the suggested SPT. In this model, a significant patientcentred risk factor for all three outcomes (tooth loss, more than one tooth lost and recurrence of periodontitis during SPT) was the duration of SPT for more than 10 years ($p = 0.0004$, 0.0001 and 0.0215, respectively) (Table 6). Additionally, the older patient age contributed to the risk for tooth loss, while the high-risk profile at T1 ($p = 0.0454$) contributed significantly to the risk for recurrence of periodontitis (Table 6).

In the second multivariate regression analysis model, the six clinical parameters determining the risk profile after APT were included: four continuous clinical risk parameters (BOP percentage, number of pockets with PPD $\geqslant 5$ mm, number of teeth lost and percentage bone loss in relation to the patient's age), as well as smoking (yes or no) and diabetes (yes or no). Gender, age and compliance with SPT were also included.

In this model, patient age ($p = 0.0014$) and bone loss in relation to the patient's age ($p = 0.0075$) were identified as significant patientcentred risk factors for *tooth loss during SPT* (Table 7).

Patient compliance ($p = 0.0041$), BOP ($p = 0.0101$) and bone loss in relation to the patient's age ($p = 0.0516$) were identified as the significant patientcentred risk factors for *loss of more than one tooth* during SPT (Table 7).

Of these variables, only smoking ($p = 0.0029$) was found to contribute significantly to the risk for *recurrence of periodontitis* (Table 7).

Discussion

The purpose of this analysis was to determine the effect of a proposed PRA model (Lang & Tonetti 2003) evaluated after the completion of APT on the association with recurrence of periodontitis and tooth loss in patients on SPT and to explore the influence of patient compliance with SPT on predictability.

Compliance

In the present study, all patients with a low-risk profile for recurrence of periodontal disease were fully compliant and attended the suggested recall visit at least once a year. However, patients with a moderate-risk profile complied 85%, and patients with a high-risk profile were compliant in only 53%. These results indicate that compliance with SPT decreases as the risk profile increases, and hence the need for more frequent SPT increases. The same trend has been demonstrated in a study with university patients (Brägger et al. 1992) and a recent study (Rieder et al. 2004) in a private practice situation. This, in turn, means that patients in need of more frequent SPT are also those who may have compliance problems, thereby jeopardizing the maintenance of treatment outcomes.

Table 6. Multivariate logistic regression analysis model for *any tooth loss, loss of more than one tooth* and *recurrence of periodontitis* during supportive periodontal therapy (SPT)

Patient characteristics	Any tooth loss			Loss of more than one tooth			Recurrence of periodontitis		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Age at T1 < 35	1			1			1		
Age at T1 35–44	2.39	0.72–8.01	0.1565	1.35	0.36–5.08	0.6568	0.93	0.31–2.79	0.8954
Age at T1 45–54	**4.00**	**1.22–13.10**	**0.022**	1.96	0.54–7.11	0.3058	0.94	0.32–2.74	0.9156
Age at T1 55–64	**4.90**	**1.33–18.02**	**0.0169**	2.04	0.50–8.36	0.3241	0.86	0.27–2.79	0.8041
Age at T1 ⩾ 65	3.02	0.50–18.15	0.2278	2.37	0.34–16.33	0.3816	1.33	0.24–7.20	0.7433
Gender: female *versus* male	1.20	0.61–2.37	0.6017	1.31	0.62–2.78	0.4745	1.09	0.57–2.10	0.7958
Compliance erratic *versus* full	1.02	0.44–2.38	0.9687	1.99	0.84–4.68	0.1165	0.63	0.28–1.43	0.2744
SPT: ⩾ 10 years *versus* < 10 years	**4.12**	**1.89–8.99**	**0.0004**	**5.13**	**2.22–11.88**	**0.0001**	**2.31**	**1.13–4.73**	**0.0215**
Risk at T1: low	1			1			1		
Risk at T1: moderate	0.84	0.22–3.16	0.7951	0.60	0.13–2.76	0.5161	3.54	0.70–17.96	0.1277
Risk at T1: high	2.40	0.57–10.10	0.2326	1.95	0.39–9.71	0.4159	**5.79**	**1.04–32.34**	**0.0454**

Bold values signify risk factors ($p < 0.05$).

Table 7. Multivariate logistic regression analysis model for *any tooth loss, loss of more than one tooth* and *recurrence of periodontitis* during supportive periodontal therapy (SPT) with patientcentred parameters and clinical parameters determining the risk profile at T1

Patient characteristics and clinical parameters	Any tooth loss			Loss of more than one tooth			Recurrence of periodontitis		
	O.R.	95% CI	*p*-value	O.R.	95% CI	*p*-value	O.R.	95% CI	*p*-value
Compliance: erratic versus full	1.89	0.84–4.24	0.1218	**3.28**	**1.46–7.39**	**0.0041**	0.95	0.49–2.27	0.8948
Age at T1 (per 1 year older)	**1.07**	**1.03–1.12**	**0.0014**	1.04	1.00–1.09	0.0734	1.00	0.96–1.04	0.8998
Gender: female *versus* male	1.18	0.59–2.36	0.6382	1.25	0.59–2.67	0.5635	1.02	0.52–1.99	0.9640
Continuous									
BOP (per 1% increase in bleeding sites per patient)	1.01	0.99–1.04	0.3407	**1.04**	**1.01–1.07**	**0.0101**	1.00	0.97–1.02	0.7145
PPD ⩾ 5 mm (per 1 one pocket more)	1.01	0.94–1.09	0.7346	0.98	0.90–1.06	0.5474	1.02	0.95–1.10	0.5454
Teeth lost (per one tooth more lost)	0.94	0.86–1.04	0.2370	0.95	0.86–1.06	0.3780	0.98	0.89–1.07	0.6053
Bone loss/age (per 1% more bone loss in relation to patient's age)	**3.72**	**1.42–9.75**	**0.0075**	**2.69**	**0.99–7.29**	**0.0516**	1.31	0.55–3.11	0.5453
Diabetes: yes *versus* no	6.56	0.72 –59.31	0.0943	3.43	0.65 –18.04	0.1453	1.07	0.21–5.37	0.9336
Smoking: yes *versus* no	1.28	0.60–2.74	0.5206	1.52	0.68–3.40	0.3108	**3.03**	**1.46–6.27**	**0.0029**

Bold values signify risk factors ($p < 0.01$). BOP, bleeding on probing; PPD, probing pocket depth.

Tooth loss

Tooth loss was analysed as a final outcome of disease progression. From a total of 3571 teeth, 258 corresponding to 7.2% of all teeth present after APT were lost during SPT of 9.5 ± 4.5 years. This average tooth loss is slightly greater than that reported in studies on SPT of a similar duration (König et al. 2001: 3%, Fardal et al. 2004: 1.5%, Carnevale et al. 2007: 0.9%, Faggion Jr. et al. 2007: 5.5%). However, in most of these studies, the patients were compliant with the proposed frequency of maintenance visits.

Compliant patients in the present study lost only 4.7% of teeth, while patients with erratic compliance lost 14.7% of the teeth present after APT. It is evident that tooth loss in the moderate- and high-risk profile, erratic compliant patients was three times as great than that for the patients fully compliant with the suggested SPT. Consequently, the increased risk for tooth loss in patients with a moderate- or a high-risk profile may be compensated by strict adherence to an SPT programme tailored to the individual needs of the higher risk profile patients.

Moreover, the results of the present study are in agreement with those of a recent study of a similar duration (Eickholz et al. 2008), in which 6.7% of the teeth (155 teeth from 2301 teeth present after APT) were lost during SPT. Out of the 100 patients included in that study, 53 complied with the scheduled SPT and attended the SPT visits regularly, while 47 were erratic compliers.

Half of the patients (49.4%) in the present study maintained all their teeth during approximately 10 years of SPT. For the compliant patients, 53.4% maintained all the teeth, whereas only 38.1% of the erratic compliers maintained all teeth. The results for compliant patients are similar to those of a study of a similar duration on 142 compliant periodontal patients (König et al. 2002). In that study, 64% of the patients maintained all their teeth over a mean of 11.7 years.

In the present study, the patients demonstrating only erratic compliance with the SPT suggestions lost statistically significantly more teeth (3.12; SD 4.5 teeth/patient) than compliant patients (1.08; SD 1.6 teeth/patient) (Kruskal–Wallis test, $p = 0.0067$). This outcome is in agreement with the results of a retrospective study on 92 patients with a mean SPT duration of 6.7 years (Checchi et al. 2002). Erratic compliers in that study displayed a 5.6 times greater risk for tooth loss than did fully compliant patients. Likewise, a fivefold greater tooth loss for only erratically compliant patients when compared with fully compliant patients was demonstrated in the retrospective study previously mentioned for 100 patients and a 10-year SPT duration (Eickholz et al. 2008) In that study, patients

attending the SPT visits regularly lost 0.55 (SD 1.0) teeth/patient and the patients with irregular attendance lost 2.68 (SD 4.4) teeth/patient.

It is evident from the results of the present and other studies mentioned that fully complying with suggested maintenance schedules will substantially reduce the risk for tooth loss when compared with only erratic compliance. Hence, it appears that the strict adherence to SPT protocols will – at least to a great extent – compensate for a high-risk profile for recurrence of periodontitis.

On the other hand, the results of the present study appear to be in disagreement with those of a large cohort study with 505 patients (Miyamoto et al. 2006). In that study, after at least 10 years of maintenance, fully compliant patients had lost more teeth than did erratic compliers. This seemingly contradictory result was interpreted to be attributable to the fact that the decision for tooth extraction made by dental health professionals influenced tooth loss rather than patient compliance.

In the present study, 45% of low- and moderate-risk profile patients lost at least one tooth during the observation period. In high-risk profile patients, however, 61% of the patients experienced the loss of at least one tooth, indicating that patients with a high-risk profile display a substantially greater tooth loss than the patients with a moderate- or a low-risk profile. In this regard, the determination of individual risk profiles for recurrence of periodontitis has clinical relevance.

Patients with a high-risk profile after APT lost significantly more teeth (2.59; SD 3.9) than patients with a moderate- (1.02; SD 1.8) or a low-risk profile (1.18; SD 1.9).

Compliant patients with both a moderate- and a high-risk profile after APT lost less teeth than did patients with only erratic compliance, but of the same risk profile (0.80; SD 1.3 teeth/patient *versus* 2.21; SD 3.2 and 1.71; SD 2.2 *versus* 3.57; SD 5.0, respectively). However, owing to a small number of cases, this difference was not statistically significant in patients with a high-risk profile ($p = 0.3338$) and reached borderline significance ($p = 0.0511$) in patients with a moderate-risk profile. Hence, the trend towards statistical significance is obvious.

These results demonstrate that compliance with the recommended frequency for SPT may – at least partially – compensates the risk for tooth loss in patients with a high- or a moderate-risk profile.

As revealed by the multivariate regression analysis, the only patient-centred parameter of significance for predicting any tooth loss or loss of at least one tooth was the duration of SPT, i.e. the observation interval of more than 10 years. In addition, for the association with any tooth loss, patients over 45 years of age were at a higher risk compared with younger patients. This, in turn, points to the long-term development of periodontitis leading to tooth loss only after periods of prolonged duration, i.e. more than 10 years.

Analyses of the influence of the individual parameters of the PRA on the prediction of any tooth loss identified the percentage of bone loss in the posterior region in relation to the patients' age as the only factor of significance besides the age factor. However, for the prediction of the loss of more than one tooth, erratic compliance ($p = 0.004$), percentage of BOP ($p = 0.010$) and the percentage of bone loss in the posterior region in relation to the patient's age ($p = 0.052$) were significant factors.

In accordance with the results of the present study, a recently published report of 100 patients on 10 years of maintenance (Eickholz et al. 2008) indicated that a high-risk profile (defined according to Lang & Tonetti 2003 after APT) showed a statistically significantly association with future tooth loss ($p < 0.0001$). Moreover, similar to the results of the present analysis, irregularly performed SPT ($p < 0.0001$) as well as age ($p < 0.0001$) correlated with higher tooth loss (Eickholz et al. 2008).

Recurrence of periodontitis

Applicaton of the definition for progressive periodontitis (Tonetti & Claffey 2005) specified in the 5th European Workshop on Periodontology, namely the presence of at least two teeth with $\geqslant 3$ mm proximal attachment loss between two observation periods, in the present study revealed 43.1% of cases to be classified as *progressive cases* after approximately 10 years of SPT.

Studies exploring the rate of recurrence of periodontitis according to a defined set of criteria during long-term maintenance are scarce. However, a recent study identified 13.3% of the patients with progressive periodontitis after only 12 months of SPT (Lorentz et al. 2009). In that study, progressive periodontitis was defined as the change of CAL at one site that exceeded 3 mm. Obviously, this definition is at variance with that used in the present study.

In multivariate logistic regression analysis, a high-risk patient profile according to the PRA model at the end of APT was associated with recurrence of periodontitis. Another significant factor for recurrence of periodontitis was an SPT duration of more than 10 years.

From the six clinical parameters used in determining periodontal risk (PRA), only smoking ($p = 0.0029$) was found to be a significant predictor for the recurrence of periodontits. These results are consistent with numerous studies that have demonstrated cigarette smoking to be a risk factor for periodontitis progression during the SPT (e.g. Grossi et al. 1995, Kerdvongbundit & Wikesjö 2000, Haffajee & Socransky 2001, Preshaw et al. 2005, Kibayashi et al. 2007, Jansson & Lagervall 2008, Matuliene et al. 2008). Although there is a longitudinal study in which this relationship could not be established, SPT every 3–4 months was enough to prevent progression of periodontitis in smokers and non-smokers (Fischer et al. 2008). However, it has to be realized that the duration of this study was only 3 years.

In conclusion, the present study, evaluating 10 years of SPT, has validated the PRA as defined by Lang & Tonetti (2003). Patients with a high-risk profile after APT were more prone to recurrence of periodontitis and to tooth loss than patients with a moderate- or a low-risk profile.

Furthermore, fully compliant patients were at a lower risk for recurrence of periodontitis and tooth loss than erratically compliant patients. Hence, the susceptibility for recurrence of periodontitis of patients with a high-risk profile may – at least partially – be reduced by strictly adhering to suggested SPT protocols tailored to the needs of the patient according to the PRA.

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Clinical Relevance

Scientific rationale for the study: A PRA has been developed on the basis of six periodontal parameters at a patient level. The PRA defines three categories of patients with a low-, a moderate- or a high-risk profile, respectively. So far, the association of PRA categories for the recurrence of periodontitis and tooth loss during SPT remains unclear.

Principal findings: Patients with a high-risk profile after APT were more prone to recurrent periodontitis and greater tooth loss during SPT than patients with a moderate- or a low-risk profile. Erratically compliant patients were at a greater risk for tooth loss than patients fully compliant with the SPT recommendations.

Practical implications: The present study, evaluating 10 years of SPT, has validated the PRA as defined by Lang & Tonetti (2003). PRA, therefore, represents a suitable method to identify high-risk profile patients after APT. For such patients, the compliance with suggested SPT protocols is of utmost importance, because erratic compliance may result in a higher risk for tooth loss. Hence, full compliance with tailored SPT may compensate for higher susceptibility for recurrence of disease.