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Influence of residual pockets on progression of periodontitis and tooth loss: Results after 11 years of maintenance

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Abstract

Background: Limited evidence exists on the significance of residual probing pocket depth (PPD) as a predictive parameter for periodontal disease progression and tooth loss.

Aim: The aim of this study was to investigate the influence of residual PPD $\geqslant 5$ mm and bleeding on probing (BOP) after active periodontal therapy (APT) on the progression of periodontitis and tooth loss.

Material and Methods: In this retrospective cohort, 172 patients were examined after APT and supportive periodontal therapy (SPT) for 3–27 years (mean 11.3 years). Analyses were conducted using information at site, tooth and patient levels. The association of risk factors with tooth loss and progression of periodontitis was investigated using multilevel logistic regression analysis.

Results: The number of residual PPD increased during SPT. Compared with PPD $\leqslant 3$ mm, PPD = 5 mm represented a risk factor for tooth loss with odds ratios of 5.8 and 7.7, respectively, at site and tooth levels. The corresponding odds ratios for PPD = 6 mm were 9.3 and 11.0 and for PPD $\geqslant 7$ mm 37.9 and 64.2, respectively. At patient level, heavy smoking, initial diagnosis, duration of SPT and PPD $\geqslant 6$ mm were risk factors for disease progression, while PPD $\geqslant 6$ mm and BOP $\geqslant 30\%$ represented a risk for tooth loss.

Conclusion: Residual PPD $\geqslant 6$ mm represent an incomplete periodontal treatment outcome and require further therapy.

Key words: bleeding on probing; clinical attachment level; maintenance care; periodontitis; progression; residual probing depth; risk factors; supportive periodontal therapy; tooth loss

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The goal of periodontal therapy is to arrest progressive attachment loss, and hence to prevent further disease progression, and eventually tooth loss.

Conflict of interest and source of funding statement

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Several longitudinal clinical studies documented the successful achievement of such treatment goals, provided that comprehensive periodontal therapy was followed by regularly attended and performed maintenance care (Knowles et al. 1979, Axelsson & Lindhe 1981a, b, Pihlström et al. 1983, Kaldahl et al. 1996, Rosling et al. 2001). With a rigid maintenance care programme over 30 years, further attachment loss concomitant with an almost complete prevention of dental caries lesions was demonstrated (Axelsson et al. 2004).

However, even in groups of patients who were extremely well controlled and in which periodontal stability was maintained over long periods of time (Lindhe & Nyman 1984, Rosling et al. 2001), recurrence of the periodontal disease was not completely prevented. Episodes of clinical attachment and tooth loss clustered in sub-populations of approximately one-fourth (Lindhe & Nyman 1984) to one-fifth (Rosling et al. 2001) of the population treated. It is evident from such studies that high susceptibility patients who may exhibit disease

recurrence could have been identified after active therapy based on their clinical and radiographic parameters. Such parameters included proportions of bleeding on probing (BOP), numbers of residual pockets following active therapy, as well as the amount of attachment and bone loss experienced.

At the patient level, there is very limited evidence to support the idea that residual pockets after active periodontal therapy (APT) represent a risk factor for further disease progression. In a study with 16 patients suffering from advanced periodontitis (Claffey & Egelberg 1995), the presence of high proportions of residual probing pocket depth (PPD) $\geqslant$ 6 mm after initial periodontal therapy indicated patient susceptibility for further attachment loss over a 42-month period. In contrast, the full-mouth plaque and BOP scores of these patients demonstrated little association with probing attachment loss. At the site level, BOP, however, was found to be a useful predictor of subsequent deterioration.

In a retrospective study (Lang et al. 1986), repeated BOP at the same site during supportive periodontal therapy (SPT) was found to be a parameter with a limited, but statistically significant positive predictive value for attachment loss. In a subsequent prospective cohort, absence of BOP was established as a parameter with a very high negative predictive value (98.5%) indicating periodontal stability (Lang et al. 1990, Joss et al. 1994).

In a review from the World Workshop in Periodontics (1996), BOP as a risk factor at the site level for the progression of periodontitis in a treated and maintained population had an odds ratio (OR) of 2.79 [95% confidence interval (CI) 1.03–7.57] (Armitage 1996). In the same review, residual PPD $\geqslant$ 6 mm had an OR of 9.7 (95% CI 4.1–22.6) for periodontal disease progression (Armitage 1996).

A systematic review (Renvert & Persson 2002) identified only one above-mentioned study (Claffey & Egelberg 1995) at the patient level for the use of residual probing depth, BOP and furcation status following initial periodontal therapy to predict further attachment and tooth loss.

Due to the lack of longitudinal data for determining risk factors for periodontitis progression in susceptible patients, the aims of the present retrospective longitudinal study were to investigate the influence of residual PPD $\geqslant$ 5 mm and BOP after APT on (1) the progression of periodontitis and (2) tooth loss.

Material and Methods

This retrospective cohort consisted of patients with periodontal disease 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.

Out of the 392 treated patients, 199 could be recruited and re-examined during the year 2005 (T2). The remaining 193 patients were either deceased, moved away from the area or were too frail to participate in the re-examination.

For the patients to be included in this study, at least two additional sets of periodontal and radiographic examinations had to be available: at baseline (before therapy, T0) and at the end of APT (T1). Twenty-seven patients could not be analysed owing to the lack of a complete documentation. Thus, 172 patients, 95 (55.2%) females and 77 (44.8%) males, between 14 and 69 years of age (mean 45 $\pm$ 11 years) at baseline (T0) were included in the analysis.

Experimental subjects

At baseline (T0), complete clinical periodontal and radiographic examinations were performed. The number of teeth and implants was defined. PPD and gingival recession were measured at six sites per tooth/implant to calculate the level of clinical attachment (CAL). BOP was recorded at four sites per tooth/implant, and full-mouth bleeding scores (FMBS) were obtained. Tooth mobility (Ramfjord 1959) as well as furcation involvement of multirooted teeth (Hamp et al. 1975) were assessed. A full-mouth periapical X-ray status was performed and radiographic bone loss was evaluated. The same periodontal and radiographic examinations were performed at the end of the active therapy (T1) and at re-evaluation (T2). However, at re-evaluation (T2), the full-mouth radiographs were replaced by orthopantomograms.

Definition of periodontitis

Retrospectively, using the periodontal parameters of baseline examination (T0), all patients were classified as having Level 1 or 2 periodontitis according to the definition of a periodontal case proposed at the 5th European Workshop on Periodontology (2005) (Tonetti & Claffey 2005):

> Level 1 – presence of proximal attachment loss of $\geqslant$ 3 mm in $\geqslant$ 2 non-adjacent teeth.
> Level 2 – presence of proximal attachment loss of $\geqslant$ 5 mm in $\geqslant$ 30% of teeth present.

Periodontal therapy

All patients were treated according to the protocol of comprehensive periodontal therapy (Lang & Löe 1993). Case presentation and oral hygiene instructions were performed and cause-related initial periodontal therapy was carried out (scaling and root planing under local anesthesia if necessary). After evaluation of the outcome of initial therapy, periodontal surgery was performed if indicated. Finally, prosthetic therapy using dental implant or tooth-supported fixed dental prostheses (FDP) was performed. Some patients refused surgical therapy and were provided with SPT after initial cause-related therapy.

Following completion of comprehensive periodontal treatment, patients attended the SPT programme at the clinic at University of Berne or were referred back to private practitioners for SPT.

Re-evaluation

The time point of re-evaluation (T2) was after a mean of 11.3 $\pm$ 4.9 years (range 3–27 years) after completion of the APT. The mean patient age at re-evaluation was 56.6 $\pm$ 11 years (range 24–83 years).

Smoking and health status

Using a questionnaire at re-evaluation examination (T2), smoking habits at time points T0 and T2, health status at time point T2 and frequency of recall visits during SPT were assessed.

Progression of periodontal disease

A case was defined as being progressive, according to the definition proposed at the 5th European Workshop on Periodontology (2005) (Tonetti & Claffey

2005), if there were at least two teeth with ⩾3 mm proximal attachment loss 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. Stratified descriptive information was calculated using site, tooth and patient as the unit of analysis. The association of risk factors with tooth loss was investigated using multivariable, multilevel logistic regression analysis from which ORs with 95% CI are reported. In theses analyses, tooth was the unit of analysis. The multilevel models allow and adjust for the correlation of tooth characteristics in the same patient. A multilevel logistic regression analysis for tooth loss including both patient and tooth characteristics was also performed. Furthermore, we investigated whether or not the association of risk factors with tooth loss differed by years of SPT by including appropriately constructed terms for effect modification in the logistic regression models. For this analysis, we grouped SPT as <10 years and 10 years or more. Wald tests were calculated to assess the statistical significance of the included effect modification terms.

As progression of periodontitis is an outcome defined on the patient, no multilevel structure was present and standard multivariable logistic regression models were fitted to obtain ORs for describing the association of patient-level risk factors with progression of periodontitis.

Two-sided *p*-values were assessed and statistical significance was declared for *p*-values <0.05. All analyses were conducted using Stata® version 10 (StataCorp, College Station, TX, USA).

Results

Diagnosis

At T0, 100% of the patients fulfilled the case requirements for Level 1 periodontitis definition. Eighty-nine percent (153 cases) fulfilled the case requirements for Level 2 periodontitis definition. According to the AAP classification (1999), the latter were generalized advanced chronic periodontitis cases.

Smoking

At the re-evaluation visit (T2), 163 patients reported retrospectively their smoking habits at baseline (T0). Out of those, 42.3% (69) were non-smokers, 24.5% (40) were former smokers and 33.1% (54) were current smokers. Of those 54 current smokers, seven patients were light smokers (1–9 cigarettes/day), 15 moderate (10–19 cigarettes/day) and 32 heavy smokers (⩾20 cigarettes/day).

At the re-evaluation examination (T2), 168 patients reported their current smoking status: 36.9% (62) were non-smokers, 35.7% (60) were former smokers and 27.4% (46) were current smokers. Of the current smokers, 13 patients were light smokers (1–9 cigarettes/day), 12 moderate (10–19 cigarettes/day) and 21 heavy smokers (⩾20 cigarettes/day).

Health

Nine patients had rheumatic diseases, eight suffered from diabetes mellitus (type 2), 30 from hypertension and 18 patients had heart and circulation diseases.

SPT

After APT, 98 patients attended the SPT programme at the clinic of University of Berne according to their individual needs. The other 73 patients had been referred back to their private practitioner for SPT. The information about one patient was lacking. One hundred sixty-eight patients reported on the frequency of their SPT visits. Eight patients reported to have had an SPT recall less than once a year, 20 patients once a year, 82 patients twice and 58 patients three to four times a year. If analysed separately, those patients having their SPT at the University clinic had shorter recall intervals: 94.9% of the patients had a recall appointment ⩾2 times/year in comparison with 67.6% of the patients in private practice. There were only 5.1% of the patients who had a recall appointment once or less per year at the University clinic in comparison with 32.4% in private practice (Table 1). These differences were highly statistically significant ($p < 0.0001$).

Residual probing pocket depth (PPD)

Site-based data

Mean PPD at baseline (T0) was 4.0 mm (SD ± 1.9), at the end of therapy (T1) 2.6 mm (SD ± 0.9) and at re-evaluation (T2) 2.1 mm (SD ± 1.2).

The prevalence of each PPD at baseline (T0), at the end of therapy (T1) and at re-evaluation (T2) is summarized in Table 2a. During the maintenance period (T1–T2), the prevalence of shallow PPD (1–3 mm) did not change substantially. The prevalence of PPD = 4 mm was reduced (from 8.0% to 5.8%) and the prevalence of residual PPD⩾5 mm increased from 2.9% to 4.3%.

Patient-based data

Mean PPD per patient at baseline (T0) was 4.0 mm (SD ± 0.8), at the end of therapy (T1) 2.6 mm (SD ± 0.4) and at re-evaluation (T2) 2.1 mm (SD ± 0.4).

The prevalence of various PPDs per patient was calculated before (T0) and after (T1) therapy as well as at re-evaluation (T2; Table 2b). In general, the number of residual PPD⩾5 mm per patient increased during the period of SPT from 4.1 (SD ± 5.3) to 5.4 (SD ± 6.8).

The prevalence of PPD⩾5 mm per patient was calculated at each observation point and is presented in Table 3. At baseline (T0), only one patient (0.6%) had no sites with PPD⩾5 mm, 1.2% of the patients had one to four, 4.6% of the

Table 1. Frequency of supportive periodontal therapy (SPT) visits according to the location

Frequency of SPT visits	Location of SPT provided				
	private dentist, $n = 71$ (42.3%)		University, $n = 97$ (57.7%)		total, $n = 168$ (100%)
No SPT	1 (1.4%)	32.4%*	0	5.1%	1 (0.6%)
<1 × per year	6 (8.5%)		1 (1.0%)		7 (4.2%)
1 × per year	16 (22.5%)		4 (4.1%)		20 (11.9%)
2 × per year	30 (42.2%)	67.6%*	52 (53.7%)	94.9%	82 (48.8%)
3–4 × per year	18 (25.4%)		40 (41.2%)		58 (34.5%)
Total	100%		100%		100%

*$p < 0.0001$.

Table 2a. Site-based data

PPD (mm)	No. of pockets					
	at baseline (T0)		at end of therapy (T1)		at re-evaluation (T2)	
⩽3	51.4% (12 758)		89.1% (21 014)		89.9% (20 034)	
4	17.5% (4341)		8.0% (1862)		5.8% (1285)	
5	9.6% (2371)		1.9% (452)		2.2% (495)	
6	10.3% (2555)		0.8% (198)	2.9%	1.1% (242)	4.3%
⩾7	11.2% (2803)		0.2% (54)		1.0% (222)	
Total	4138 teeth 24 828 sites		3835 teeth, 95 implants 23 580 sites		3541 teeth, 172 implants 22 278 sites	

Percentage (*n*) of sites with each probing pocket depth (PPD) at baseline (T0), at the end of therapy (T1) and at re-evaluation (T2).

Table 2b. Patient-based data

PPD (mm)	Mean no. of pockets/patient ± SD					
	at baseline (T0)		at end of therapy (T1)		at re-evaluation (T2)	
⩽3	74.2 ± 28.8		122.2 ± 23.2		116.5 ± 28.0	
4	25.2 ± 11.8		10.8 ± 9.8		7.5 ± 5.7	
5	13.8 ± 7.2		2.6 ± 3.2		2.9 ± 3.1	
6	14.8 ± 10.1	44.9 ± 26.6	1.2 ± 2.2	4.1 ± 5.3	1.4 ± 2.2	5.4 ± 6.8
⩾7	16.2 ± 15.3		0.3 ± 1.0		1.2 ± 2.7	

The mean number of each probing pocket depth (PPD) per patient at baseline (T0), at the end of therapy (T1) and at re-evaluation (T2).

Table 3. Patient-based data

No. of PPD⩾5 mm	Baseline (T0), *n* = 172	End of therapy (T1), *n* = 172	Re-evaluation (T2), *n* = 172
0	0.6% (1)	28.5% (49)	18.6% (32)
1–4	1.2% (2)	40.1% (69)	40.7% (70)
5–8	4.6% (8)	16.3% (28)	18.0% (31)
⩾9	93.6% (161)	15.1% (26)	22.7% (39)

Percentage of patients (*n*) with different number of residual probing pocket depth (PPD)⩾5 mm at baseline (T0), at the end of therapy (T1) and at re-evaluation (T2).

patients had five to eight and 93.6% of the patients had ⩾9 such sites. After active therapy (T1), 28.5% of the patients had no residual PPD⩾5 mm, 40.1% of the patients had one to four, 16.3% of the patients had five to eight and 15.1% of the patients had ⩾9 residual PPD⩾5 mm. At re-evaluation (T2), 11 years after active therapy, 18.6% of the patients had no sites with residual PPD⩾5 mm, 40.7% of the patients had one to four, 18.0% of the patients had five to eight and 22.7% of the patients had ⩾9 such sites. Again, the number of residual PPD per patient increased during the SPT. By and large, this increase was associated with the location where the SPT was provided. The number of patients having ⩾9 sites with PPD⩾5 mm did not change in the patient group who received the SPT at the University clinic (from 18.4% to 17.4%). In contrast, the number of patients having ⩾9 sites with PPD⩾5 mm increased significantly in the group of patients who received their maintenance therapy in private practices (from 11.0% to 30.1%; Table 4).

The prevalence of PPD⩾5 mm in non-smokers, light and heavy smokers at the end of active therapy (T1) and at re-evaluation (T2) is presented in Fig. 1. It is evident that the prevalence of residual pockets increased substantially from 31.3% to 52.4% in the heavy smokers. The percentage of the non-smokers yielding ⩾9 sites with PPD⩾5 mm increased from 7.3% to 14.8%.

BOP

The data of 160 patients could be analysed owing to the fact that the BOP data of 12 patients belonging to the oldest cohort of >20 years of SPT were missing. These data were analysed using the patient as the unit of analysis.

The mean FMBS per patient at T0, T1 and T2 was 65.8%, 18.7% and 22.6%, respectively (Table 6).

Patients were grouped into three groups according to the FMBS: 0–9%, 10–24% and ⩾25%. At baseline (T0), there were no patients with an FMBS of 0–9%, 2.5% of the patients presented with an FMBS of 10–24% and 97.5% of the patients had an FMBS of ⩾25%. After active therapy (T1), the results were 29.4%, 45.0% and 25.6%, and at re-evaluation (T2), the corresponding values were 15.1%, 50.0% and 34.9%, respectively (Table 5).

Tooth loss

Influence of pocket depth on tooth loss (not accounting for BOP)

Tooth loss at re-evaluation (T2) was analysed according to the site-level PPD and according to the deepest PPD of a tooth at the end of active therapy (T1).

Site-level analysis. About 63.5% of sites with PPD⩾7 mm at the end of therapy (T1), 30.7% of sites with PPD = 6 mm, 21.7% of sites with PPD = 5 mm and 13.7% of sites with PPD = 4 mm were lost at re-examination (T2; Table 6, Fig. 2).

Increased PPD was strongly associated with tooth loss in multilevel logistic regression analysis ($p<0.0001$). Compared with pockets with PPD = 1–3 mm, PPD = 4 mm had an increased odds of tooth loss during SPT [OR = 2.6 (CI: 95%, 2.1–3.1)], as well as PPD = 5 mm [OR = 5.8 (CI: 95%, 4.3–7.9)], PPD = 6 mm [OR = 9.3 (CI: 95%, 6.2–13.9)] and PPD⩾7 mm [OR = 37.9 (CI: 95%, 17.9–80.2)] (Table 7).

The impact of the increase of 1 mm PPD on tooth loss was derived from the same multivariable logistic regression models, using different reference categories. With the exception of the step between PPD = 5 mm and 6 mm, the increase by 1 mm PPD increased the odds, and therefore the probability, of tooth loss in a statistically significant way ($p<0.001$; Fig. 2).

Tooth-level analysis. Tooth-level analysis was done according to the deepest PPD of a tooth at the end of therapy (T1). About 55.3% of the teeth with deepest PPD⩾7 mm, 22.2% of the teeth

Table 4. Patient-based data

No. of PPD ⩾5 mm	End of therapy (T1), $n = 171$		Re-evaluation (T2), $n = 171$	
	location of SPT (%)		location of SPT (%)	
	University	private practice	University	private practice
0	30.6	26.0	18.4	19.2
1–4	38.8	41.1	42.8	38.4
5–8	12.2	21.9	21.4	12.3
⩾9	18.4	11.0	17.4	30.1

Percentage of patients with different number of residual probing pocket depth (PPD) ⩾5 mm at the end of therapy (T1) and at re-evaluation (T2) according to the location of supportive periodontal therapy (SPT).

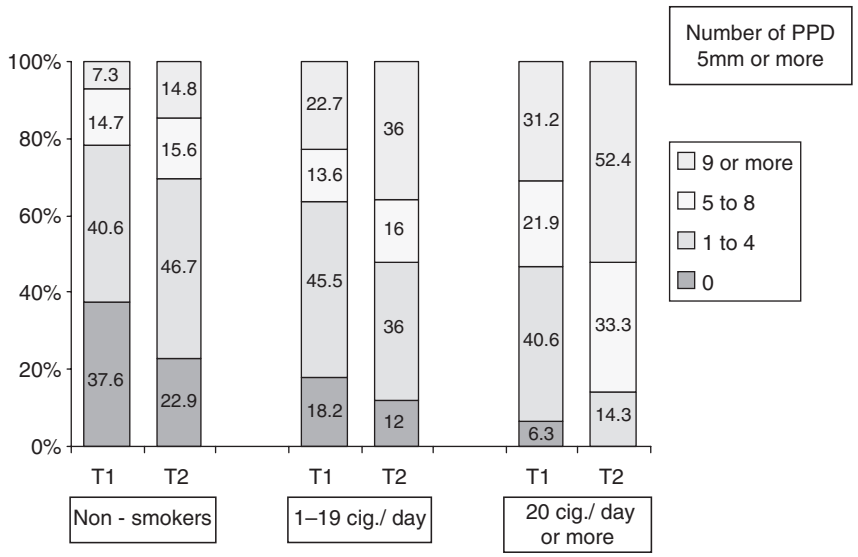

Fig. 1. Distribution of number of sites with residual probing pocket depth (PPD) ⩾5 mm among the patients according to smoking habits. T1, end of therapy; T2, re-evaluation after supportive periodontal therapy (SPT); 163 patients at T1 and 168 at T2.

Table 5. Patient-based data

FMBS	Baseline (T0), $n = 160$	End of therapy (T1), $n = 160$	Re-evaluation (T2), $n = 160$
Mean ± SD (%)	65.8 ± 18.4	18.7 ± 13.6	22.6 ± 13.2
0–9%	0%	29.4%	15.1%
10–24%	2.5%	45.0%	50.0%
⩾25%	97.5%	25.6%	34.9%
Total	100%	100%	100%

Percentage of patients with different full mouth bleeding score (FMBS) at baseline (T0), at the end of therapy (T1) and at re-evaluation (T2).

with deepest PPD = 6 mm, 17.1% of the teeth with deepest PPD = 5 mm and 8.7% of the teeth with deepest PPD = 4 mm were lost at re-examination (T2; Table 6, Fig. 2).

We investigated the impact of deepest PPD as an independent variable for tooth loss during SPT, using a multilevel logistic regression model. Compared with teeth with the deepest PPD between 1 and 3 mm, teeth with the deepest PPD = 4 mm at T1 had a 2.5 times higher odds of tooth loss (CI: 95%, 1.8–3.6). Teeth with the deepest PPD of 5 mm had an OR for tooth loss of 7.7 (CI: 95%, 4.8–12.3), those with a deepest PPD of 6 mm an OR of 11.0 (CI: 95%, 6.1–20.1), and those with a deepest PPD ⩾7 mm an OR of 64.2 (CI: 95%, 24.9–165.1; Table 7).

The impact of the increase of 1 mm PPD on tooth loss was derived from the same multivariable logistic regression models, using different reference categories. With the exception of the step between a deepest PPD of 5 mm and a deepest PPD of 6 mm, the increase by 1 mm PPD increased the odds, and therefore the probability, for tooth loss in a statistically significant way ($p < 0.001$; Fig. 2).

Influence of pocket depth accounting for BOP on tooth loss

The percentage of teeth lost during the SPT according to site-level PPD or the deepest PPD of a tooth and absence/presence of BOP at the end of therapy (T1) was analysed. The data are presented in Table 6 and Fig. 3.

Site-level analysis. If presence/absence of BOP was analysed for each PPD, always more teeth were lost if the site was BOP-positive compared with BOP-negative sites (Table 6, Fig. 3). Because of small numbers of PPD = 6 mm and PPD ⩾7 mm, the differences reached statistical significance only between the BOP-positive and BOP-negative sites with PPD = 1–3, 4 ($p < 0.0001$) and 5 mm ($p = 0.01$).

The crude OR of BOP for tooth loss was 2.6 (CI: 95%, 2.3–3.0). If PPD was combined with presence of BOP as independent variables in a multilevel regression model of tooth loss as an outcome, BOP-positive sites had a higher odds ratio of tooth loss [OR = 2.0 (CI: 95%, 1.7–2.4)], when controlling for PPD. If, in addition to the presence of BOP, the PPD was 4 mm, the OR for tooth loss was 2.3 (95% CI 1.9–2.4) when compared with a PPD up to 3 mm. For a PPD of 5 mm, the OR was 4.8 (95% CI 3.5–6.6), with a PPD of 6 mm, the OR was 7.2 (95% CI 4.7–11.0), and with a PPD 7 mm or larger, the OR for tooth loss was 25.6 (95% CI 11.4–57.1).

Tooth-level analysis. At the tooth level, only teeth with the deepest PPD of 4 mm yielded a statistically significant ($p = 0.002$) higher tooth loss with positive BOP values (Fig. 3).

If only BOP was the independent variable and PPD was not accounted for (crude BOP OR), the odds of tooth loss was 2.6 times higher for BOP-positive teeth [OR = 2.6 (CI: 95%,

Table 6. Site and tooth-level analysis

PPD at T1 (mm)	Total no. of pockets at T1	Lost at T2	No. of pockets BOP$^+$ at T1*	Lost at T2	No. of pockets BOP$^-$ at T1*	Lost at T2
Site level						
⩽3	21 014	1323 (6.3%)	2992	319 (10.7%)	16 582	950 (5.1%)
4	1862	255 (13.7%)	635	124 (19.2%)	1113	104 (9.3%)
5	452	98 (21.7%)	236	66 (28.0%)	194	25 (12.9%)
6	199	61 (30.7%)	121	39 (32.2%)	72	20 (27.8%)
⩾7	54	33 (63.5%)	37	25 (67.6%)	11	5 (45.5%)
Tooth level						
⩽3	2581	119 (4.6%)	608	39 (6.4%)	1801	70 (3.9%)
4	901	78 (8.7%)	318	36 (11.3%)	515	27 (5.2%)
5	275	47 (17.1%)	140	30 (21.4%)	120	13 (10.8%)
6	135	30 (22.2%)	77	17 (22.1%)	53	12 (22.6%)
⩾7	38	21 (55.3%)	26	15 (57.7%)	8	3 (37.5%)

*The summary of bleeding on probing (BOP)-negative and BOP-positive sites is not equal to the total number of pockets, because BOP data from 12 patients are missing.

Tooth loss at re-evaluation (T2) according to the probing pocket depth (PPD) and to the BOP at the end of active therapy (T1).

For the tooth level, the deepest PPD of the tooth was used to categorize the tooth.

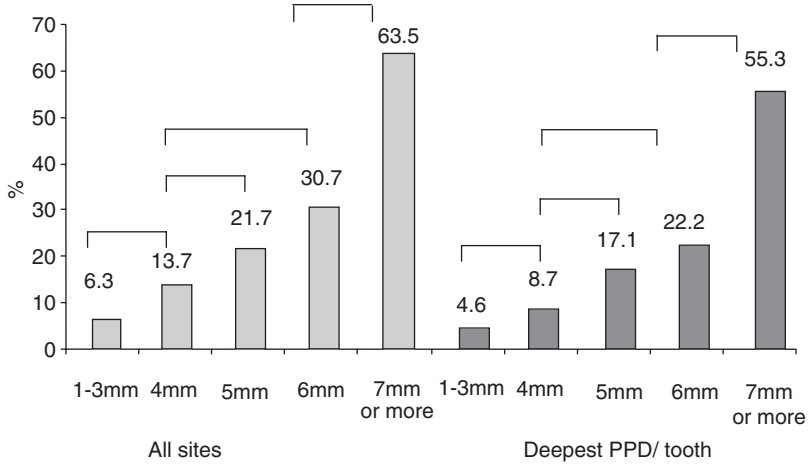

Fig. 2. Site and tooth-level analysis. Percentage of teeth lost at T2 depending on the site-level probing pocket depth (PPD) or the deepest PPD of a tooth (tooth level) at the end of therapy (T1), not accounting for bleeding on probing (BOP). Values within brackets are significantly different at $p<0.001$; p-values derived from multilevel logistic regression analysis.

Table 7. Results from multilevel logistic regression models for the association of site probing pocket depth (PPD) and deepest PPD of a tooth at the end of therapy (T1) with tooth loss during supportive periodontal therapy [not accounting for bleeding on probing (BOP)]

PPD (mm)	Site level			Tooth level		
	OR	95% CI	p-value	OR	95% CI	p-value
⩽3	1.0					
4	2.6	2.2–3.1	<0.0001	2.5	1.8–3.6	<0.0001
5	5.8	4.3–7.9	<0.0001	7.7	4.8–12.3	<0.0001
6	9.3	6.2–13.9	<0.0001	11.0	6.1–20.1	<0.0001
⩾7	37.9	17.9–80.2	<0.0001	64.2	24.9–165.1	<0.0001

For the tooth level, the deepest PPD of the tooth was used.

1.9–3.6)]. If, however, the deepest PPD of a tooth was combined with the presence of BOP as independent variables in a multilevel regression model of tooth loss, the BOP increased the odds of tooth loss [OR = 1.9 (CI: 95%, 1.3–2.6)]. If, in addition to presence of BOP, the deepest PPD was 4 mm, the OR was 2.1 (95% CI 1.4–3.1) when compared with teeth with a deepest PPD below 3 mm. For a deepest PPD of 5 mm, the OR was 7.0 (95% CI 4.2–11.6), with a deepest PPD of 6 mm, the OR was 9.9 (95% CI 5.3–18.6), and with a deepest PPD ⩾7 mm, the OR for tooth loss was 43.6 (95% CI 15.3–124.3).

In multivariable, multilevel logistic regression analysis for tooth loss, the following parameters were included: the deepest PPD of a tooth, the greatest clinical attachment loss, the worst furcation involvement of a tooth and the greatest grade of tooth mobility. Risk factors for tooth loss at this tooth level were the following combination of parameters: PPD > 4 mm at the end of active therapy (risk increased with every millimetre), furcation involvement, increased mobility (Grade 2) and CAL ⩾7 mm (Table 8).

Analysis of patient characteristics

Before APT (T0), 24.1 ± 3.3 teeth per patient were present (not accounting for third molars or substituting implants, totally 4138 teeth).

During active therapy, 303 teeth were extracted (1.76 teeth/patient) leaving 22.3 ± 4.1 teeth per patient at T1. One tooth had to be extracted in 20.4% of the patients, two teeth had to be extracted in 18.0% of the patients, three teeth in 8.7% of the patients and four teeth in 8.1% of the patients. In the remaining 9.9% of the patients, ⩾5 teeth were extracted. All teeth were kept in 34.9% of the patients.

At re-evaluation (T2), 20.6 ± 5.1 teeth per patient were present. During the SPT in 54.7% of the patients, 294 teeth were lost additionally (1.71 teeth/patient), corresponding to 7.7% of all teeth present ($n = 3835$) at T1. One tooth was extracted in 19.8% of the patients, two teeth were extracted in 14.6% of the patients, three teeth in 6.4% of the patients and four teeth in 2.9% of the patients. Eleven percent of the patients had lost ⩾5 teeth. Approximately 20% of the patients lost ⩾3 teeth, accounting for 71.4% (210) of all teeth lost in the population during the observation period.

In 86.1% of the patients, zero to three teeth were lost. In 12.2% of the patients, four to nine teeth were lost, and in 1.5% of the patients, ⩾10 teeth were lost. The tooth loss in later six patients accounts for 26.5% (78) of the teeth lost.

During the entire observation period, 14.4% (597/4138) of the teeth were lost:

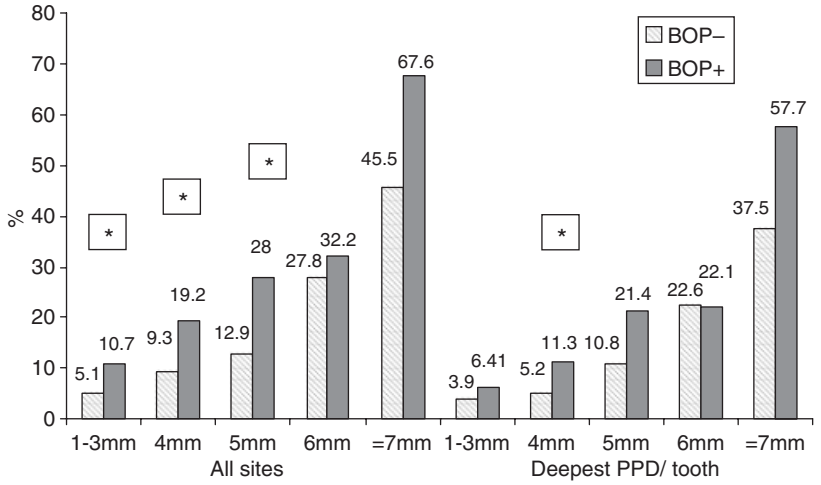

Fig. 3. Site and tooth-level analysis. Percentage of teeth lost at T2 depending on the site-level probing pocket depth (PPD) or the deepest PPD of a tooth (tooth level) and presence/absence of bleeding on probing (BOP) at the end of therapy (T1). Values marked with (*) are significantly different; *p*-values derived from multilevel logistic regression analysis.

Table 8. Results from multivariable, multilevel logistic regression model for the association of tooth characteristics with tooth loss during supportive periodontal therapy (no patient characteristics included)

Variables	OR	95% CI	*p*-value
Maximum PPD ⩽ 3 mm	1.0 (ref.)		
Maximum PPD = 4 mm	1.6	1.0–2.3	0.034
Maximum PPD = 5 mm	3.0	1.7–5.2	<0.0001
Maximum PPD = 6 mm	2.7	1.3–5.5	0.005
Maximum PPD ⩾ 7 mm	9.9	3.3–30.2	<0.0001
No furcation involvement	1.0 (ref.)		
Maximum furcation involvement class 1	2.1	1.3–3.4	0.002
Maximum furcation involvement class 2	4.6	2.5–8.6	<0.0001
Maximum furcation involvement class 3	12.6	5.3–30.2	<0.0001
No tooth mobility	1.0 (ref.)		
Mobility grade 1	1.5	0.9–2.3	0.097
Mobility grade 2	3.8	1.6–8.7	0.002
Mobility grade 3	5.3	0.2–176.8	0.353
Maximum CAL 0–3 mm	1.0 (ref.)		
Maximum CAL = 4 mm	1.8	0.9–3.4	0.061
Maximum CAL = 5 mm	1.3	0.7–2.5	0.441
Maximum CAL = 6 mm	1.6	0.8–3.1	0.197
Maximum CAL ⩾ 7 mm	3.1	1.6–6.2	0.001
Maximum CAL ⩾ 10 mm	13.3	5.1–34.8	<0.0001

CAL, clinical attachment level; PPD, pocket probing depth; OR, odds ratio; CI, confidence interval.

303 (50.8%) of those were lost during APT and 294 (49.2%) during the SPT.

In multivariable, multilevel logistic regression analysis for tooth loss, the following parameters were included: gender, age, years of SPT, FMBS at T1, smoking habits, health status, the location of SPT, presence and number of residual PPD ⩾ 5 mm after active therapy, presence and number of residual PPD ⩾ 6 mm after active therapy, number of teeth lost after active therapy and severity of periodontitis at baseline.

Because the FMBS scores (grouped at 0–9%, 10–24%, ⩾25%), the number of teeth lost after active therapy and the number of residual PPD ⩾ 5 mm after active therapy were found to have no influence on tooth loss as univariate predictors, these variables were excluded from the final model.

In the final model for tooth loss, significant patient-centred risk factors were FMBS ⩾ 30% ($p = 0.013$), the diagnosis of Level 2 ($p = 0.012$), the years of SPT over 10 years ($p = 0.008$) as well as the presence of residual PPD ⩾ 6 mm after APT ($p = 0.053$; Table 9).

Combined analysis of patient and tooth characteristics and association of risk factors over time

A multilevel logistic regression model that included simultaneously both patient and tooth characteristics was also fitted. The association of residual pocket depths with tooth loss remained strong and estimated ORs were only slightly different from those obtained from the analysis including only the tooth characteristics (Table 10). Thus, adjusting for patient characteristics did not reduce the strength of the association with tooth characteristics.

Furthermore, separate analyses in patients with less and in those with 10 or more years of SPT were run. Formal interaction tests between the two groups of patients did not reveal significant differences in the strength of the association of teeth characteristics with tooth loss for any of the teeth characteristics. Estimated ORs were broadly similar but 95% CI were generally large which resulted in certain being statistically significant different from 1 and others not (Table 10). The results provided weak evidence that the impact of a maximal PPD >6 mm was stronger in the first 10 years and somewhat reduced for patients with 10 years or more of SPT. Similarly, there was weak evidence that a maximal CAL >9 mm had a somewhat stronger impact in patients with 10 or more years of SPT than in patients with <10 years SPT.

Progression of periodontal disease

According to the definition chosen [⩾2 teeth with ⩾3 mm proximal attachment loss between the end of APT (T1) and re-evaluation (T2)] 43.3% of cases had to be classified as *progressive cases*.

In a standard logistic regression analysis for periodontitis progression at the patient level, the following parameters were included: gender, age, years of SPT, FMBS (⩾30%) at T1, smoking habits (non-smokers, smokers 1–19 cigarettes a day, heavy smokers with ⩾20 cigarettes a day), health status, the location of SPT, the presence and number of residual PPD ⩾ 5 mm after active therapy, the presence and number of residual PPD ⩾ 6 mm after active therapy, the number of teeth lost after

active therapy and the severity of periodontitis at baseline.

Of these variables, only heavy smoking ($p = 0.007$), the duration of SPT exceeding 10 years ($p = 0.026$), initial Level 2 diagnosis ($p = 0.027$) and presence of at least one site with PPD $\geqslant$ 6 mm ($p = 0.025$) or presence of $\geqslant$ 9 sites with PPD $\geqslant$ 5 mm ($p = 0.028$) were found to contribute significantly to the risk of periodontitis progression (Table 11).

Discussion

The purpose of the present study was to evaluate the role of residual pockets as defined by a PPD $\geqslant$ 5 mm following APT in predicting further progression of periodontitis and tooth loss. For this purpose, a patient cohort that was individually maintained from 3 to 27 years was analysed after a re-examination. Obviously, progression of periodontitis was not to be expected in the years immediately following active therapy. Hence, a 3-year period of supportive therapy was chosen before the patients were eligible for the present study. Of the 172 patients re-examined, the mean duration of SPT was 11.3 years, indicating that a majority of the patients were well maintained for over 10 years. The present cohort, however, does not provide a sizable control population that was poorly compliant with the recommended SPT protocol. Only eight patients visited the SPT programme less than once a year. Hence, the analysis focused on a patient cohort treated for advanced periodontitis and – by and large – well maintained for a decade.

Residual pockets

Eighty-nine percent of the patients included in this retrospective longitudinal study were treated for severe periodontal disease. At completion of APT, 28.5% of the patients were free of residual pockets, which had been defined as PPD $\geqslant$ 5 mm. About 71.5% of the patients had an average of 4.1 (SD $\pm$ 5.3) residual pockets. After a mean of 11 years of SPT, the number of residual PPD $\geqslant$ 5 mm per patient increased to 5.4 (SD $\pm$ 6.8).

These findings are in agreement with other studies on SPT (Tonetti et al. 1998, König et al. 2002, Carnevale et al. 2007a, b). In one study originating from the same department, but analysing a different cohort (Tonetti et al. 1998), a significant increase in the number of periodontal pockets of PPD $\geqslant$ 4 mm per patient from 4.5 $\pm$ 0.4 to 8.6 $\pm$ 0.4 was observed during a mean SPT period of only 5.5 $\pm$ 4.4 years. Although, in another study (Carnevale et al. 2007a), despite of the fact that all pockets $>$ 3 mm were eliminated after APT, 1.5% of sites exhibited recurrent pockets with PPD $\geqslant$ 4 mm (0.2% PPD $\geqslant$ 6 mm), with recalls every 3.4 $\pm$ 0.8 months during a mean observation period of 7.8 $\pm$ 3.2 years.

The increase in the number of residual PPD $\geqslant$ 5 mm in the present study was dependent on the location where SPT was provided and the smoking habits.

Although the percentage of patients with $\geqslant$ 9 sites with residual PPD $\geqslant$ 5 mm did not change over the observation period of 11 years in the group of the patients who remained at the University clinic for SPT (from 18.4% to 17.4%), there were nearly three times as many patients with $\geqslant$ 9 sites with residual PPD $\geqslant$ 5 mm in the group who received the maintenance therapy in private practices (11.0% *versus* 30.1%). This may be associated with the fact that SPT appointments at the University clinic were provided more often, because nearly all the patients (94.9%) received SPT at least twice a year in comparison with only 67.6% of the patients in private practices. These data confirmed the results of a study on maintenance performed at a University clinic and at referring private practices (Axelsson & Lindhe 1981b) and pointed to the importance of a rigid SPT regime after APT in order to prevent further disease progression.

At the end of active therapy (T1) 37.6% of the non-smokers, 18.2% of the smokers and only 6.3% of the heavy smokers were free of residual PPD $\geqslant$ 5 mm. After a mean of 11 years of SPT, 22.9% of the non-smokers, 12.0% of the smokers and no heavy smokers were free from residual pockets. The increase of the number of residual pockets per patient was clearly associated with the increased consumption of cigarettes. The same findings were demonstrated in another study, where a dose dependant relationship between smoking and increase of residual PPD $\geqslant$ 5 mm after a mean of 7.3 $\pm$ 1.5 years of maintenance was revealed (Rieder et al. 2004). Obviously, smoking represents a substantial risk factor for disease progression as represented by increased numbers of residual pockets during maintenance.

Table 9. Results from multivariable, multilevel logistic regression analysis for the association of patient characteristics with tooth loss during supportive periodontal therapy

Patient characteristics	OR	95% CI	*p*-value
FMBS $<$ 30%	1.0 (ref.)		
FMBS $\geqslant$ 30%	2.2	1.2–4.2	0.013
Non-smoking	1.0 (ref.)		
Smoking 1–19 cig./day	1.4	0.7–2.9	0.346
Smoking $\geqslant$ 20 cig./day	1.2	0.5–2.7	0.624
Healthy	1.0 (ref.)		
Diabetes mellitus	2.8	0.9–9.1	0.085
University *versus* private practice	0.7	0.4–1.1	0.113
Gender: male *versus* female	1.1	0.7–1.9	0.593
Diagnosis: level 2 *versus* level 1	4.2	1.4–12.7	0.012
SPT: $\geqslant$ 10–15 years *versus* $<$ 10 years	2.2	1.2–3.9	0.008
SPT: $\geqslant$ 16 years *versus* $<$ 10 years	6.2	3.2–12.1	$<$ 0.0001
$\geqslant$ 1 site with PPD $\geqslant$ 6 mm	1.7	1.0–2.8	0.053

The model controlled for age of the patients but did not include tooth characteristics.
PPD, pocket probing depth; SPT, supportive periodontal therapy, OR, odds ratio; CI, confidence interval; FMBS, full mouth bleeding score.

Tooth loss

In the present study, 14.4% of teeth were lost during the entire periodontal therapy. During active therapy, 50.8% and during SPT 49.2% of these teeth were extracted. This tooth loss was similar to that reported in a study of shorter duration (Tonetti et al. 2000). Slightly lower prevalence rates of tooth loss were, however, reported in other studies with similar observation periods (König et al. 2002, Fardal et al. 2004, Carnevale et al. 2007b, Faggion et al. 2007, Eickholz et al. 2008). In the

Table 10. Results from different multivariable, multilevel logistic regression models for the association of tooth characteristics with tooth loss during supportive periodontal therapy adjusted for patient characteristics

Variables	Model								
	Model controlled for SPT			Model only for patients with SPT less than 10 years			Model only for patients with SPT more than 10 years		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Maximum PPD ⩽ 3 mm	1.0 (ref.)			1.0 (ref.)			**1.0** (ref.)		
Maximum PPD = 4 mm	1.5	.98–2.3	0.063	*1.0*	*0.4–2.5*	*0.98*	**1.7**	**1.0–2.7**	**0.032**
Maximum PPD = 5 mm	2.8	1.6–5.0	0.001	*2.3*	*0.7–7.6*	*0.18*	**3.0**	**1.5–5.9**	**0.001**
Maximum PPD = 6 mm	2.4	1.2–5.0	0.016	*2.1*	*0.5–9.5*	*0.33*	**2.5**	**1.1–5.7**	**0.031**
Maximum PPD ⩾ 7 mm	9.3	3.1–27.9	<0.0001	*18.0*	*2.6–125.4*	*0.003*	**6.0**	**1.6–22.2**	**0.007**
No furcation involvement	1.0 (ref.)								
Maximum furcation involvement class 1	2.2	1.4–3.6	0.001	*1.8*	*0.6–5.2*	*0.26*	**2.3**	**1.4–4.1**	**0.002**
Maximum furcation involvement class 2	5.1	2.7–9.5	<0.0001	*4.9*	*1.4–17.2*	*0.013*	**4.8**	**2.3–10.0**	**<0.0001**
Maximum furcation involvement class 3	12.5	5.3–29.7	<0.0001	*14.2*	*2.9–70.5*	*0.001*	**12.3**	**4.3–34.6**	**<0.0001**
Maximum CAL 0–3 mm	1.0 (ref.)								
Maximum CAL = 4 mm	1.5	0.8–2.9	0.222	*2.0*	*0.4–9.7*	*0.400*	**1.4**	**0.7–2.9**	**0.350**
Maximum CAL = 5 mm	1.2	0.6–2.3	0.671	*2.0*	*0.4–9.2*	*0.375*	**1.0**	**0.5–2.1**	**0.987**
Maximum CAL = 6 mm	1.5	0.8–3.0	0.245	*1.8*	*0.4–9.0*	*0.469*	**1.4**	**0.7–3.1**	**0.348**
Maximum CAL 7–9 mm	3.0	1.5–6.0	0.001	*3.4*	*0.7–16.9*	*0.126*	**3.0**	**1.4–6.4**	**0.005**
Maximum CAL ⩾ 10 mm	12.5	4.8–32.6	<0.0001	*8.9*	*1.2–68.4*	*0.035*	**16.0**	**5.2–49.1**	**<0.0001**

All three models included mobility, and the patient characteristics age, gender smoking, health status and treatment in private practice or at university. Each model is characterised by a particular font for easy comparison. Italics stands for the model for patients with less than 10 years of SPT, and bold depicts the model for patients with more than 10 years of SPT.
CAL, clinical attachment level; PPD, pocket probing depth; SPT, supportive periodontal therapy, OR, odds ratio; CI, confidence interval.

Table 11. Results from standard multivariable logistic regression analysis for the association of patient characteristics with progression of periodontal disease during supportive periodontal therapy

Patient characteristics	OR	95% CI	*p*-value
FMBS ⩾30% *versus* <30%	0.7	0.3–2.0	0.531
Smoking 1–19 cig./day *versus* non-smoking	1.8	0.7–4.7	0.268
Smoking ⩾ 20 cig./day *versus* non-smoking	5.9	1.6–21.3	0.007
Diabetes mellitus *versus* healthy	0.7	0.1–4.6	0.726
University *versus* private practice	0.8	0.4–1.6	0.478
Gender: male *versus* female	1.2	0.6–2.6	0.571
Diagnosis: level 2 *versus* level 1	0.3	0.1–0.9	0.027
SPT: ⩾10–15 years *versus* <10 years	2.5	1.1–5.6	0.026
SPT: ⩾16 years *versus* <10 years	1.8	0.7–4.9	0.237
⩾1 site with PPD ⩾6 mm	2.4	1.1–5.1	0.025

The model controlled for age of the patients.
PPD, pocket probing depth; FMBS, full mouth bleeding score; SPT, supportive periodontal therapy, OR, odds ratio; CI, confidence interval.

present study, 89% of the patients were classified to suffer from severe periodontitis, while other studies reported on the treatment of a smaller proportion of patients with severe periodontitis (Tonetti et al. 2000, König et al. 2002, Fardal et al. 2004, Carnevale et al. 2007a, b, Eickholz et al. 2008). This, in turn may explain the difference in prevalence of tooth loss in the various studies.

While in the present study, approximately 50% of the teeth to be extracted were removed during active and the other half during supportive therapy, other study reported on a ratio 63% *versus* 37% (König et al. 2002). One recent study reported that 90% of the extractions had been performed during active therapy and only 10% during SPT (Carnevale et al. 2007b), and in another recent study (Eickholz et al. 2008, Pretzl et al. 2008) tooth loss was attributed to the compliance of the patients with the supportive care programme offered with a ratio of 1:5 for compliant *versus* non-compliant patients. The latter patients lost an average of 2.68 teeth in 10 years compared with only 0.55 teeth in 10 years for the compliant patient group. The variability in these proportions certainly reflects variations in the treatment approaches of the different institutions and the intensity of the enforced maintenance visits during SPT at the various clinics (Eickholz et al. 2008). While the study by Carnevale et al. (2007a, b) documented a ''pocket elimination approach'' as an ultimate treatment goal, the present study represents a ''pocket reduction and access to the root surface'' approach leaving residual pockets after active therapy, and hence maintaining slightly jeopardized teeth for a longer period of time.

During the mean observation period of 11 years, 45.4% of the patients in the present study did not experience any further tooth loss. In a study on 12 years of SPT (Rosling et al. 2001), only 36% of the patients did not experience tooth loss, and 24% of them lost ⩾4 teeth. This patient group was subsequently identified as a high susceptibility group for periodontal disease (HSG). In a group identified as a ''normal susceptibility'' group (NG), 74% of the subjects retained all teeth during the 12 years of SPT. Obviously, the susceptibility of the host to the periodontal infection should not be underestimated when tooth loss is evaluated over time.

The true sequelae of periodontal disease is tooth loss. Hence, the success of periodontal therapy and maintenance over years should be assessed by evaluating tooth loss. Increased PPDs and clinical attachment loss represents only surrogate parameters helping to describe

disease progression that finally leads to tooth loss. The clinicians may, therefore, benefit from probing assessments after APT and during maintenance in order to facilitate prediction of further progression of periodontal disease and tooth loss. However, it has to be realized that, in the present study, the reason for tooth loss remains unknown as it does in many other studies (Tonetti et al. 2000, Carnevale et al. 2007a, b, Eickholz et al. 2008). It may be expected that teeth with PPD < 5 mm were extracted for reasons other than periodontitis progression such as root fractures or sequelae of endodontic treatment.

Using PPD at the site level and identifying the deepest PPD of a tooth at the tooth level, associations with tooth loss were analysed. Each residual PPD had statistically significant ($p < 0.001$) increased OR for tooth loss during SPT if compared with PPD of ⩽3 mm both at the site and tooth level.

In multilevel regression analyses, a residual PPD ⩾ 6 mm after APT was a statistically significant predictor for future tooth loss at the site, tooth and patient level. This, in turn, means that sites with PPD ⩾ 6 mm are to be considered incomplete periodontal treatment outcomes hereby confirming suggestions made in one previous prospective study in 16 patients (Claffey & Egelberg 1995). In essence, the presence of residual PPD ⩾ 6 mm represented a much stronger risk factor for tooth loss than BOP alone. However presence of BOP appears to even further increase the probability for the respective tooth to be lost with ORs of 2.0 (CI: 95%, 1.7–2.4) and 1.9 (CI: 95%, 1.3–2.6) at the site and tooth level, respectively. This is further documented by the fact that patient FMBS ⩾ 30% was significantly associated with tooth loss ($p = 0.013$).

In subjects on SPT for < 10 years only PPD ⩾ 7 mm were associated with a significantly higher risk for tooth loss (OR 18.0; 95% CI 2.6–125.4), whereas in the subjects on SPT for 10 years or more, already PPD = 5 and 6 mm were significantly associated with tooth loss. From a clinical point of view, this may indicate an increased need for supportive therapy and re-treatment of residual pockets as patients age and present with recurrent pockets during maintenance.

Progression of periodontitis

According to the definition for disease progression specified at the 5th European Workshop on Periodontology (Tonetti & Claffey 2005; ⩾2 teeth with ⩾3 mm proximal attachment loss between two observation periods), 43.3% of cases in the present study were *progressive* during the maintenance period. This is nearly double as much as in a study over 14 years of SPT (Lindhe & Nyman 1984) where 25% of patients had at least one site with further attachment loss > 2 mm. In the study over 12 years of maintenance (Rosling et al. 2001) about 70% of the patients in the ''high susceptibility'' group had at least eight teeth with ⩾2 mm additional proximal probing attachment loss during the SPT, while in the ''normal group'', < 10% of the patients fulfilled these criteria. Again, the susceptibility of the patients to periodontitis appeared to play a major role not only in tooth loss, but in disease progression as well. Moreover, the differences in the magnitude of the patient group, who have exhibited the progression of periodontitis arrive from the definition of disease progression, which is slightly different in all above-mentioned studies.

In the present study, the smoking patient who smoked ⩾20 cigarettes per day, the patient having been on SPT for > 10 years, the presence of at least on site with residual PPD ⩾6 mm or ⩾9 sites with residual PPD ⩾ 5 mm after active therapy and the diagnosis of ''severe periodontitis'' (Level 2; Tonetti & Claffey 2005) were identified as significant risk factors for the progression of periodontitis.

As opposed to the recent study (Eickholz et al. 2008), the patients in the cohort of the present study were treated by a number of clinicians during a long range of calendar years (1978–2002). The treatment philosophy applied, however, may only have changed to a limited degree during this period owing to the increasing popularity of oral implants to replace missing teeth. Also, the decision to extract teeth during SPT was made by a number of clinicians at the University of Berne as well as in private practices. Hence, the intention to extract or maintain a compromised tooth may have been variable.

In conclusion, within limitations of this study, residual PPD ⩾ 6 mm after APT represented a risk factor for both progression of periodontitis (Tonetti & Claffey 2005) and tooth loss during the SPT at the patient, tooth and site level. Multiple sites (⩾9) with residual PPD ⩾ 5 mm also represented a risk for further progression of periodontitis at the patient level as defined by Tonetti & Claffey (2005).

BOP at the site and tooth level increased the probability of tooth loss with OR 2.0 and 1.9, respectively. At the patient level, FMBS ⩾ 30% represented a risk factor for tooth loss.

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Clinical Relevance

Scientific rationale for the study: Little evidence is available on the significance of the presence of residual pockets after APT influencing disease progression and tooth loss during maintenance.

Principle findings: In the patients of the present retrospective analysis after an average of 11 years of SPT, 50% of the teeth extracted were lost during APT and the remainder during SPT. The number of residual pockets increased during the 11 years. Residual pockets with PPD $\geqslant$ 6 mm were risk factors for both disease progression and tooth loss.

Practical implications: Residual PPD $\geqslant$ 6 mm represent an incomplete periodontal treatment outcome and need further therapy.