Received: 22 April 2020 | Revised: 9 June 2020 | Accepted: 21 June 2020

DOI: 10.1111/jre.12786

ORIGINAL ARTICLE

Journal of PERIODONTAL RESEARCH WILEY

Retrospectively analysed tooth loss in periodontally compromised patients: Long-term results 10 years after active periodontal therapy—Patient-related outcomes

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Funding information
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Abstract

Background and Objective: Long-term tooth retention is the ultimate goal of periodontal therapy. Aim of this study was to evaluate tooth loss (TL) during 10 years of supportive periodontal therapy (SPT) in periodontal compromised patients and to identify factors influencing TL on patient level.

Material and Methods: Patients were re-examined 120 ± 12 months after active periodontal therapy. TL and risk factors [smoking, initial diagnosis, SPT adherence, interleukin-1 polymorphism, cardiovascular diseases, age at baseline, bleeding on probing (BOP), change of practitioner, insurance status, number of SPT, marital and educational status] influencing TL on patient level were assessed.

Results: One-hundred patients (52 female, mean age 65.6 ± 11 years) lost 121 of 2428 teeth (1.21 teeth/patient; 0.12 teeth/patient/y) during 10 years of SPT. Forty-two of these were lost for periodontal reasons (0.42 teeth/patient; 0.04 teeth/patient/y). Significantly more teeth were lost due to other reasons ($P < .001$). Smoking, baseline severity of periodontitis, non-adherent SPT, positive interleukin-1 polymorphism, marital and educational status, private insurance, older age at baseline and BOP, small number of SPT were identified as patient-related risk factors for TL ($P < .05$).

Conclusion: During 120 ± 12 months of SPT, only a small number of teeth was lost in periodontally compromised patients showing the positive effect of a well-established periodontal treatment concept. The remaining risk for TL should be considered using risk-adopted SPT allocation.

KEYWORDS

long-term success, periodontal risk factors, supportive periodontal therapy, tooth loss

Clinical trial number: NCT03048045 (URL: https://clinicaltrials.gov)

1 | INTRODUCTION

Severe periodontitis is the most common non-communicable human disease,[1,2] which if untreated can result in tooth loss (TL).[3] Irrespective of the fact that TL due to periodontal disease causes enormous follow-up costs,[4] appropriate therapy of periodontitis provides a high level of oral health-related quality of life.[5] Therefore, the retention of natural teeth should be the primary treatment objective of periodontal therapy.[6-8] As numerous publications have shown, in addition to the initial removal of teeth classified as hopeless at the beginning of active periodontal therapy (APT), TL during supportive periodontal therapy (SPT) is a rare event.[6,9-11] Nevertheless, there are cases in which TL occurs more frequently during SPT than in others. Which factors influence TL in the long-term during SPT?

Most recently, various long-term studies over a follow-up period of ≥10 years determined mean annual TL rates per patient of 0.13 and 0.14, respectively, in both chronic (ChP) and aggressive periodontitis (AgP) cases during SPT.[9-12] Numerous factors at patient level associated with an increased risk of TL in SPT have already been described. For example, smoking,[11,13] non-adherence to SPT,[6,8,14] individual plaque control,[6,11] diabetes,[11,13] age,[15,16] severity of initial diagnosis,[6] marital status[11] and educational status were identified previously.[12,17] Interleukin-1 polymorphism as risk factor is controversially discussed.[6,15,18,19] Factors at tooth level (e.g. extent of bone loss, furcation involvement, abutment teeth for removable and fixed dentures) have to be distinguished from patient-level factors.

All studies have in common that they consider TL as endpoint, but rarely differentiate it further for purely periodontal tooth loss (TLP),[20,21] which should primarily be counteracted with SPT. The description of TLP is not quite simple, since there are criteria for periodontally hopeless teeth,[22-24] but they were not designed to facilitate extractions, but to describe the current condition of individual teeth.[6,8,25,26] In addition, as soon as several clinicians are involved in a study, these criteria are interpreted and applied differently, so that only approximate criteria for TLP can be assumed, especially in retrospective analyses.

Another important point is that patients in such long-term examinations are often not subject to a homogeneous treatment concept,[6,8] as adjustments (eg use of microbiological testing and/or antibiotics, risk-adapted SPT allocation) may have been made over the observed years. These adjustments would not have been made if they did not mean a benefit, which is why they may also influence the outcome of these studies.

Therefore, the objective of this retrospective study was to assess TL and TLP in periodontally compromised and homogeneously treated representative patient cohort over 10 years and to identify patient-related factors influencing both, TL and TLP, over that period in order to confirm and expand existing evidence.

2 | MATERIAL & METHODS

2.1 | Patients

First, study participants were identified by electronic and manual search in the dental performance system. All patients were required to have undergone comprehensive periodontal therapy at the Department of Periodontology of the Johann Wolfgang Goethe-University Frankfurt/Main after April 2005 encompassing oral hygiene instructions and supragingival debridement followed by subgingival debridement according to a modification[27] of the full-mouth disinfection concept (FMD) under local anaesthesia.[28] FMD was combined with adjunctive systemic antibiotics if *Aggregatibacter actinomycetemcomitans* was detected with commercially available tests. If required (e.g. persisting pocket probing depths [PPD] ≥ 6 mm), periodontal surgery was recommended. The inclusion after April 2005 guaranteed the application of a homogeneous comprehensive treatment concept[27] during APT and SPT after change of the head of the department (PE) and introduction of this concept in October 2004. Prerequisites for the participation in this retrospective cohort study were as follows:

1. Treatment according to the previously described concept
2. complete periodontal status [PPD and clinical attachment levels (CAL-V) at 6 sites/tooth, furcation involvement[29] at all furcation sites of multi-rooted teeth] before start of therapy (baseline, T0) and after completion of APT (non-surgical and if required surgical therapy) and start of SPT (T1)
3. age ≥ 18 years at the time of re-examination (T2)
4. T1-T2 = 120 ± 12 months
5. written informed consent.

Patients were consecutively recruited 120 ± 12 months after completion of APT (T1) until 100 participants were re-examined. Both non-surgical and surgical therapy had to be completed for T1. The study was approved by the Institutional Review Board for Human Studies of the Medical Faculty of the Johann Wolfgang Goethe-University (approval number 61/15). The study was registered with the United States National Library of Medicine (NIM) in the clinical trials database (URL: https://clinicaltrials.gov) with the number NCT03048045. All participants were informed in detail about the risks of participation before the start of the study and signed a written informed consent. The present work focuses on patient-related parameters, tooth-related parameters will be reported separately. Data from this patient cohort have been partially reported in part in a multicentre project.[30]

2.2 | 10-year re-examination (T2)

Four different clinicians (KN, TR, PE and HP) were involved in re-examination at T2:

1. self-reported smoking status [non-smokers (never smoked), former smokers (stopped smoking ≥5 years ago) and active smokers (stopped smoking <5 years ago or currently smoking)[31]
2. medical history
3. dental status
4. modified (6 sites per tooth) gingival bleeding index (GBI)[32] and modified (6 sites per tooth) plaque control record (PCR)[33]

5. PPD and CAL-V to the nearest 1.0 mm with a manual, millimetre-scaled rigid periodontal probe (PCPUNC 15, Hu-Friedy) at 6 sites per tooth; bleeding on probing (BOP) and suppuration 30 seconds after collection of probing parameters
6. furcation involvement at all multi-rooted teeth with Nabers probe (PQ2N, Hu-Friedy)[29,34]
7. Interleukin-1 (IL-1) polymorphism test (GenoType® IL-1, Hain Lifescience GmbH) if not already collected in clinical routine in the past; all patients who were positive for the second allele for IL-A 889 and IL-B 13953 were considered positive.
8. Patients who lost teeth were asked about the reason for this, if teeth were removed outside of the centre. For patients, whose tooth/teeth were removed in the centre or in the authors department, reasons such as periodontal diseases [combination of progressive CAL-V loss, furcation involvement II/III[29] and/or tooth mobility II/III[35]], caries or secondary caries diseases (carious lesions that could not be restored, endodontic complications that could not be managed by a revision), orthodontics (lack of space, balancing extractions), prosthetic considerations (unusable as an abutment tooth) or trauma [(longitudinal) untreatable fractures] were verified from the patient file.

Since the documentation for the justification of extraction decisions over the past 10 years has not been uniform and always plausible, the last clinical and radiological findings before the respective extraction were used—if the reason was not explicitly documented—to assess whether there were either justifiable periodontal reasons or other before mentioned reasons evident as a basis for past decision-making.

9. self-reported marital status (with partner or without partner)
10. self-reported educational status (low: primary school, intermediate secondary school, apprenticeship; high: upper secondary education)

All examiners are experienced periodontists who have completed their postgraduate training for at least 3 years. With the exception of one examiner (HP), all participating examiners have already been calibrated for two multicentre-studies.[36,37] Inter-individual calibration for HP for probing parameters PPD and CAL-V was done to the head of the department (PE) by repeated measurements within one quadrant of patients to determine a deviation of >1 mm. The indices (GBI, PCR) were not calibrated separately.

PPD and CAL-V were further categorized according to the periodontal screening and recording (PSR) categorization of PPD and the possibility to manage PPD during the SPT.[38] PPD ≤ 3 mm correspond to a PSR code of 0-2 and healthy conditions.[39,40] PPD 3-5 mm correspond to a PSR code 3 and can be treated by subgingival instrumentation during SPT. PPD ≥ 6mm correspond to a PSR code of 4 are not considered a treatment goal and have the risk of further attachment loss.[40-42]

2.3 | Patient charts

Tooth number without third molars was documented for different points of examination (T0, T1, T2).

All patients received a diagnosis according to the 1999 classification of periodontal diseases.[43] Using T0 periodontal charts, all patients were assigned to stages according to the 2018 classification based on interproximal CAL-V, teeth missing due to periodontal reasons and complexity.[44] A localized stage 3 periodontitis was classified as a moderate initial diagnosis, a generalized stage 3 or stage 4 periodontitis as well as a molar-incisor pattern with CAL-V ≥5 mm were categorized as a severe baseline diagnosis. Indices (GBI, PCR) scored during SPT were taken from patient charts. To calculate the individual periodontal risk, BOP, sites with PPD ≥ 5 mm, number of lost teeth without third molars, bone loss index, nicotine consumption and systemic/genetic factors were used according to the Periodontal Risk Assessment (PRA).[31] As a result, the risk-related SPT interval was determined according to Ramseier & Lang prospectively in each individual SPT session if new criteria were scored (e.g. PPD, BOP).[6,45] To assign adherence (adherent or non-adherent), SPT interval recommendations were compared with the intervals actually documented in the patient file. If a patient once exceeded the interval determined during SPT by more than 100%, she/he was considered to be non-adherent (Example: A recommended interval was 6 months, but the patient did not return to SPT until after 13 months).[6] In addition, patients' insurance status, a single change of practitioner during SPT period and the number of SPT visits were retrieved from the patient charts.

2.4 | Supportive periodontal therapy

All SPTs counted in this study were carried out in a university setting by dentists in collaboration with dental nurses or dental hygienists as well as by students under dentists' supervision. SPT took place over the entire follow-up period according to the same scheme,[6] provided the patient participated regularly and included the following items:

1. modified GBI[32] and modified PCR[33]
2. re-instruction and re-motivation for an effective individual plaque control
3. professional mechanical plaque removal with hand instruments and polishing by use of rotating rubber cups with polishing paste (SuperPolish; Kerr GmbH)
4. application of fluoride gel (Elmex Gelée; GABA Schweiz AG),[46]
5. Twice per year, a general dental examination and a complete periodontal status including PPD, BOP, furcation involvement and tooth mobility test were recorded. Once per year CAL-V and sensitivity testing were scored. At sites with PPD = 4 mm + BOP or PPD ≥ 5 mm, subgingival instrumentation was rendered and 1% chlorhexidine digluconate gel (Chlorhexamed 1% gel; GlaxoSmithKline GmbH) was instilled.

Patients who had a high periodontal risk and therefore were scheduled four times a year received complete SPT including the above-mentioned items 1-5 in 6 months intervals and SPT without dental and periodontal status (items 1-4) in between. If a patient exhibited >5 teeth with PPD ≥ 5 mm 2 years after reevaluating the non-surgical or surgical approach, a recurrent systematic periodontal therapy was recommended considering individual factors such as the age of the patient, time of reevaluation and/or the presence of systemic diseases.

2.5 | Statistical analysis

Data were entered twice in an excel-based (EXCEL version 16.23; Microsoft Corporation) data matrix (SA, KS). Input errors were minimized by subtracting both data sets from each other. If the result was different from "0", there was an error. Then, the original charts were retrieved, and the error corrected.

The Pearson correlation coefficient was determined to evaluate the inter-individual calibration (HP, PE) of the actually measured values for PPD and CAL-V (0-0.30: negligible agreement, 0.31-0.50: low agreement, 0.51-0.70: moderate agreement, 0.71-0.90: high agreement, 0.91-1.0: very high agreement).[47] As an estimate for the reliability of the measurements, the standard deviation (SD) of single measurements was calculated as $SD = SD_{diff}/\sqrt{2}$.

The patient was considered as statistical unit and TL during SPT was defined as the primary target variable. TL during APT (T0-T1) and SPT (T1-T2) was calculated by subtraction of number of teeth. All other parameters were secondary target parameters. Descriptive data were calculated as absolute or relative frequencies and mean ± standard deviations. Mean values and frequencies were compared using paired t test or chi-square test.

Poisson regression analysis was used to identify factors that influence TL and TLP during SPT over a follow-up period of 120 ± 12 months. The variables (a) initial diagnosis, (b) adherence to SPT, (c) mean BOP during SPT, (d) current smoking status, (e) marital status, (f) IL-1 polymorphism, (g) cardiovascular disease, (h) change of practitioner, (i) age at the beginning of therapy, (j) educational status, (k) insurance status and (l) number of SPT were entered into analysis. Third molars were excluded from the data analysis.

A significance level of 0.05 was assumed. All statistical analyses were performed with a computer software (IBM® SPSS® Statistics 24 software package; IBM).

3 | RESULTS

3.1 | Patients

After an initial search, 153 patient files were consecutively checked for compliance with the inclusion criteria of the study. Of these, 42 patients did not qualify to participate, as the inclusion criteria were not fulfilled. Thus, 111 patients were contacted, 11 of whom were considered dropouts. Four patients refused to participate in the study, 6 were no longer available at known addresses and one patient had passed away (Figure 1).

On average, 10.2 ± 0.5 years after completion of APT, 100 patients (52 females, 48 male) with a mean age of 65.6 ± 11 years at T2 were re-examined between June 2015 and August 2019. Within this cohort, nine patients were active smokers, 38 former smokers and 53 non-smokers. Between T0 and T1 four patients had stopped and one patient had started smoking. Two patients denied giving the information for marital and for educational status. 46 patients received surgical therapy in addition to their non-surgical therapy. Patients losing teeth during SPT were on average 1-2 years older at the beginning of therapy (55.4 ± 11.4 [overall TL] and 54.9 ± 12.1 years [TLP]) than patients without tooth loss (53.3 ± 10.6 years) (Table 1). Characteristics according to TL are listed in Table 1.

In addition, the percentage distributions of probing parameter PPD and CAL-V as well as of GBI, PCR and BOP at the different re-examinations can be found in Table 2. Inter-individual calibration for probing parameters showed a high-positive agreement between PE and HP for PPD ($|r| = 0.782$; $P < .001$) and CAL-V ($|r| = 0.834$; $P < .001$; overall SD for single measurements PPD: 0.55 mm; CAL-V: 0.67 mm). The number of examinations was divided as follows: KN: 9, TR: 7, PE: 32, HP: 52 examinations.

Thirteen patients additionally obtained antibiotics during APT and 11 patients received a recurrent active periodontal therapy, one of them even two times, during the observation period. Percentage distributions of PPD, CAL-V, GBI, PCR and BOP according to intake of antibiotics and need of recurrence therapy are shown in Table 3.

3.2 | Tooth loss

At the beginning of SPT (T1), 100 patients had 2391 teeth (23.91 ± 4.15 teeth/patient), (Table 4, Figure 2). Of a total of 121 teeth lost during SPT in 48 patients, only 42 teeth (0.42 ± 0.90 teeth/patient) were lost due to periodontal reasons in 24 patients.

Table 5 provides absolute data on TL and TLP, according to all categorical risk factors evaluated during the study.

A more detailed analysis of TL during SPT according to patients' adherence showed that among 48 patients who lost 121 teeth 26 patients were considered adherent and lost 70 teeth and 22 were considered non-adherent and lost 51 teeth. For periodontal reasons, 24 patients lost 42 teeth, of which 29 teeth were lost by 16 patients regularly attending SPT and 13 teeth by 8 non-adherent patients.

Risk factors.

Poisson regression analysis identified severe initial diagnosis ($P < .001$), non-adherence to SPT ($P < .001$), smoking ($P < .001$), living with partner ($P < .001$), interleukin 1-polymorphism ($P < .001$), low educational status ($P = .027$), private insurance ($P < .001$), change of practitioner ($P < .001$), age at the beginning of therapy ($P < .001$), BOP ($P < .001$) and number of SPT ($P < .001$) as risk factors for overall TL during SPT (Table 6). For TLP during SPT, there was an additional positive correlation with cardiovascular disease ($P < .001$). In

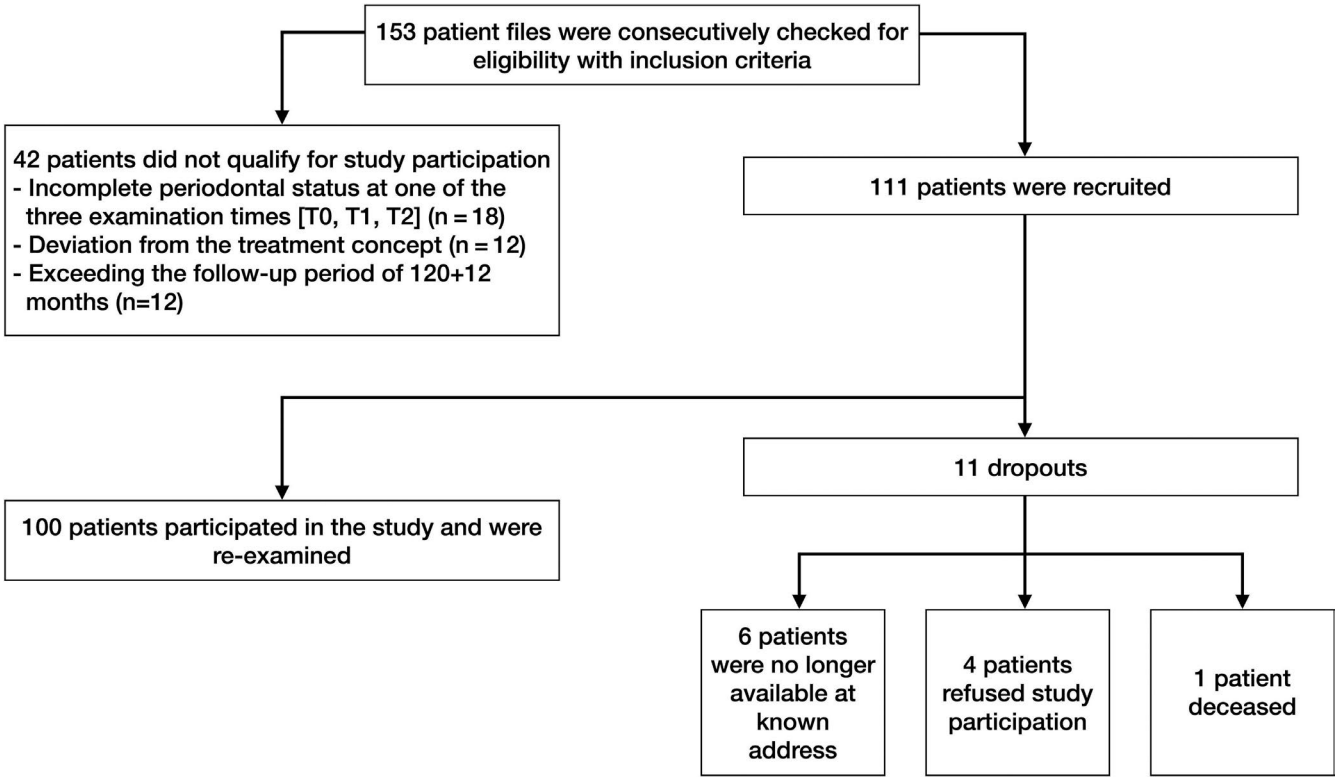

FIGURE 1 CONSORT flow diagram

contrast, no correlation could be found for interleukin-1 polymorphism and age at the beginning of therapy (Table 7). For TLP, current smoking status with a 28.6-fold increased relative risk was the strongest risk factor. Absolute numbers according to above-described correlations are given in the respective tables (Tables 6 and 7).

4 | DISCUSSION

One-hundred patients were re-examined 120 ± 12 months after APT according to TL in general and due to periodontal reasons. Patients contributed 2391 teeth after APT of which 121 were lost (1.21 teeth/patient; 0.12 teeth/patient/y) during 10 years of SPT. Forty-two of these, 121 teeth were lost for periodontal reasons. Severe initial diagnosis, non-adherence to SPT, smoking, living with partner, interleukin-1 polymorphism, low educational status, private insurance, change of practitioner, age at the beginning of therapy, BOP and number of SPT were identified as patient-related risk factors for overall TL.

How does this cohort distinguish from the cohort treated at Heidelberg?[6] All patients were treated according to a consistent concept.[27] There occurred no changes in the treatment concept during the observation period as were reported for the cohort treated at Heidelberg.[6] Thus, the recent cohort is more homogeneous according to therapy. However, whereas APT was rendered by the same practitioner (PE) at Heidelberg, different therapists (all particularly trained and experienced) rendered APT in this study. Further, the present cohort was treated approximately 10 years later. Age at start of treatment may reflect a shift of severity to older age groups in the German population (morbidity compression).[48]

For 100 patients, this study showed an average TL of 1.2 teeth per patient over 10 years. Earlier studies on tooth retention with comparable follow-up reported average TL of 1.1 teeth over 10.9 years,[20] 1.3 teeth over 10.5 years[12] and 1.6 teeth after 10 years ± 6 months.[6] The varying initial diagnoses have to be taken into account, as two studies exclusively included AgP.[12,20] Furthermore, age at start of therapy (30.8 ± 4.1,[12] 46.6 ± 10.3,[20] 46.6 ± 10.3,[6] 54.3 ± 11.0 years in the present study), which is partly due to the included initial diagnoses,[12,20] has to be considered. Both, patients' initial diagnosis and age have already been described as risk factors for TL.[6,11,16,49] Another difference was the number of patients examined, which varied between 25 and 100 patients included in these studies.

Long-term follow-up examinations over 18-20 years resulted in on average higher TL of 2.4[9] or 2.8 teeth per patient.[11] However, these differences can be explained by the risk factors mentioned above and the longer observation period.

Of all 121 lost teeth in 52 patients, 34.7% (n = 42) were lost for periodontal reasons. This was half as many as Diaz-Faes et al described with a share of 78.6%.[20] The reason for this may have been the lower number of cases (n = 25), the definition of TLP, which has not been described in more detail, and the consistently more severe initial diagnosis (AgP). From a tooth retention point of view in the present study 75 of the re-examined patients lost no teeth, 23 patients lost 1-3 teeth and 2 patients lost > 3 teeth for periodontal reasons. This is clearly

TABLE 1 Patient characteristics according to reason for TL

	Overall patients	All patients without TL	All patients with TL	All patients with TLP
	(n = 100)	(n = 52)	(n = 48)	(n = 24)
Gender (female/male)	52/48	29/23	23/25	12/12
Age (T0) [y]	54.3 ± 11.0	53.3 ± 10.6	55.4 ± 11.4	54.9 ± 12.1
Private insurance	46	25	21	9
Change of practitioner	62	30	32	14
Smoking (T2)				
Active smoker	9	4	5	2
Former or non-smoker	91	48	43	22
Diabetes (T2)	11	5	6	3
Cardiovascular disease	30	18	12	7
Interleukin-1 polymorphism				
Negative	69	34	35	19
Positive	31	18	13	5
Periodontal surgery	46	21	24	15
SPT				
Adherent	58	20	26	16
Non-adherent	42	32	22	8
Number	22.52 ± 9.16	21.96 ± 8.42	23.13 ± 9.96	27.08 ± 9.52
Initial diagnosis (T0)				
Moderate (localized stage III)	21	11	10	4
Severe (stage III/stage IV/MIP)	79 (51/22/6)	41 (27/8/6)	38 (24/14/0)	20 (15/5/0)
BOP [%]	16.8 ± 7.8	15.6 ± 7.3	18.2 ± 8.1	19.3 ± 8.5
GBI [%]	6.0 ± 5.8	4.8 ± 4.4	7.2 ± 6.9	8.8 ± 8.0
PCR [%]	31.1 ± 13.4	30.1 ± 14.3	32.2 ± 12.5	34.0 ± 10.2
Marital status				
With partner	59	26	33	15
Without partner	39	25	14	9
Educational status				
Low	33	14	19	9
High	65	37	28	14

Abbreviations: BOP, bleeding on probing; GBI, gingival bleeding index; MIP, molar-incisor pattern; PCR, plaque control record; SPT, supportive periodontal therapy; TL, tooth loss; TLP, periodontal tooth loss.

shown by the lower mean TL per patient (total: 1.21 ± 1.73; periodontal reasons: 0.42 ± 0.90) compared to the total cohort.

Martinez-Canut et al reported annual loss of 0.05 teeth per patient for periodontal reasons over an average follow-up period of 20 years, which is close to that of 0.04 teeth/patient/y in this study.[21] When comparing all the above-mentioned studies, in periodontally compromised patients TL seems to be a rare event after APT, confirming the general treatment success of periodontal therapy regardless of the concept pursued. This is supported by the results of a follow-up of a periodontally untreated patient cohort with an average loss of 13.1 teeth per patient over 40 years.[3]

As a patient-related risk factor, severity of initial diagnosis according to the Tonetti et al (2018) was associated with increased risk for both,[44] TL in general (3.6-fold risk) and due to periodontal reasons (13.2-fold risk), which confirms earlier findings according to Armitage (1999).[6,40,43,50] Furthermore, well-established factors such as current smoking status,[6,11,16,21,23,51] non-adherent SPT[6,11,12,52,53] and average BOP during SPT were confirmed.[40]

Socioeconomic factors like private insurance status ($P < .05$), low educational status ($P < .05$)[12,17] and marital status[11] were also identified as putative risk factors. Belonging to statutory or private health insurance is economically defined in the German healthcare system. The contributions of older, privately insured patients are much higher than those of the same age who are statutory insured. For this study, this means that with an average age of more than 50 years at the start of therapy, there was probably already a different economic standard between private and statutory insured participants. This is also evident in the educational and marital status 10 years

TABLE 2 Descriptive data for PPD and CAL-V according to reason for TL

	PPD [%] ≤ 3 mm			PPD [%] 4-5 mm			PPD [%] ≥ 6 mm		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
Overall	70.3	88.0	88.4	19.8	10.5	9.7	9.9	1.5	1.9
Without TL	74.8	91.0	89.5	18.2	8.1	8.9	7.0	0.9	1.6
With TL	65.4	84.6	87.3	21.5	13.2	10.6	13.1	2.2	2.1
With TLP	63.9	84.3	85.4	22.2	13.5	12.1	13.9	2.2	2.5
	CAL-V [%] ≤ 3 mm			CAL-V [%] 4-5 mm			CAL-V [%] ≥ 6 mm		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
Overall	57.1	67.4	67.4	27.4	23.7	23.2	15.5	8.9	9.4
Without TL	63.3	73.9	70.5	25.8	20.9	22.3	10.9	5.2	7.2
With TL	50.4	60.5	64.1	29.0	26.9	24.2	20.6	12.6	11.7
With TLP	48.4	57.1	56.5	30.4	29.7	29.7	21.2	13.2	13.8

	GBI [%] mean ± SD		PCR [%] mean ± SD		BOP [%] mean ± SD	
	T1	T2	T1	T2	T1	T2
Overall	5.6 ± 7.5	5.5 ± 6.9	29.8 ± 17.5	33.1 ± 18.6	13.1 ± 9.0	18.6 ± 12.0
Without TL	5.2 ± 8.3	5.3 ± 7.3	29.2 ± 17.3	28.9 ± 16.2	11.7 ± 6.9	18.3 ± 11.6
With TL	6.1 ± 6.7	5.9 ± 6.5	30.5 ± 17.9	37.6 ± 20.0	14.7 ± 10.6	18.9 ± 12.5
With TLP	8.4 ± 7.7	6.3 ± 7.6	33.3 ± 17.9	40.8 ± 16.3	15.3 ± 11.3	17.4 ± 11.1

Abbreviations: BOP, bleeding on probing; CAL-V, vertical clinical attachment level; GBI, gingival bleeding index; PCR, plaque control record; PPD, pocket probing depth; TL, tooth loss; TLP, periodontal tooth loss.

TABLE 3 Descriptive data for PPD and CAL-V according to intake of antibiotics during APT or need of recurrence therapy

		PPD [%] ≤ 3 mm			PPD [%] 4-5 mm			PPD [%] ≥ 6 mm		
	Patients [n]	T0	T1	T2	T0	T1	T2	T0	T1	T2
With antibiotics	13	58.4	84.4	82.3	22.2	13.6	14.0	19.4	2.0	3.7
Without antibiotics	87	72.1	88.5	89.3	19.4	10.1	9.1	8.5	1.4	1.6
With recurrence	11	66.5	83.4	83.2	20.1	14.8	12.5	13.4	1.9	4.1
Without recurrence	89	70.7	88.4	89.0	19.8	10.1	9.4	9.5	1.5	1.6
		CAL-V [%] ≤ 3 mm			CAL-V [%] 4-5 mm			CAL-V [%] ≥ 6 mm		
		T0	T1	T2	T0	T1	T2	T0	T1	T2
With antibiotics	13	47.3	58.0	63.4	25.7	27.1	23.9	27.0	14.9	12.7
Without antibiotics	87	58.6	68.8	68.0	27.6	23.3	23.1	13.8	7.9	8.9
With recurrence	11	55.9	67.2	59.1	24.8	23.2	26.5	19.3	9.6	14.4
Without recurrence	89	57.8	68.1	68.4	27.7	23.4	22.8	15.1	8.5	8.8

		GBI [%] mean ± SD		PCR [%] mean ± SD		BOP [%] mean ± SD	
		T1	T2	T1	T2	T1	T2
With antibiotics	13	4.3 ± 6.2	3.4 ± 3.8	26.2 ± 15.6	26.2 ± 13.7	11.8 ± 8.2	17.0 ± 11.5
Without antibiotics	87	5.8 ± 7.7	5.9 ± 7.2	30.3 ± 17.8	34.1 ± 19.0	13.3 ± 9.1	18.8 ± 12.1
With recurrence	11	5.9 ± 8.4	5.3 ± 9.4	25.9 ± 15.2	30.2 ± 16.6	15.7 ± 9.2	18.6 ± 12.3
Without recurrence	89	5.6 ± 7.5	5.6 ± 6.6	30.2 ± 17.8	33.4 ± 18.8	12.8 ± 8.9	18.6 ± 12.0

Abbreviations: BOP, bleeding on probing; CAL-V, vertical clinical attachment level; GBI, gingival bleeding index; PCR, plaque control record; PPD, pocket probing depth; TL, tooth loss; TLP, periodontal tooth loss.

TABLE 4 Descriptive data for number (lost) teeth (overall and per patient) according to reason for TL

		Number of teeth [n] mean ± SD (total)			TL [n] mean ± SD (total)	
	Patients [n]	T0	T1	T2	APT	SPT
Overall	100	24.28 ± 4.0 (2428)	23.91 ± 4.15 (2391)	22.70 ± 4.98 (2270)	0.37 ± 0.76 (37)	1.21 ± 1.73 (121)
All patients without TL (SPT)	52	25.29 ± 3.06 (1315)	25.08 ± 3.14 (1304)	25.08 ± 3.14 (1304)	0.21 ± 0.50 (11)	0.0
All patients with TL (SPT)	48	23.19 ± 4.61 (1113)	22.65 ± 4.75 (1087)	20.13 ± 5.34 (966)	0.54 ± 0.94 (26.0)	2.52 ± 1.70 (121)
All patients with TLP (SPT)	24	24.5 ± 2.23 (588)	23.96 ± 2.37 (575)	21.04 ± 3.68 (505)	0.54 ± 0.72 (13)	2.92 ± 1.74 (70)

		Anteriors [n] mean ± SD (total)			Premolars [n] mean ± SD (total)			Molars [n] mean ± SD (total)		
	Patients [n]	T0	T1	T2	T0	T1	T2	T0	T1	T2
Overall	100	11.08 ± 1.95 (1108)	11.05 ± 1.97 (1105)	10.79 ± 2.29 (1079)	7.05 ± 1.34 (705)	6.98 ± 1.40 (698)	6.62 ± 1.67 (662)	6.15 ± 1.89 (615)	5.88 ± 1.96 (588)	5.29 ± 2.18 (529)
All patients without TL (SPT)	52	11.58 ± 1.11 (602)	11.58 ± 1.11 (602)	11.58 ± 1.11 (602)	7.25 ± 1.22 (377)	7.23 ± 1.26 (376)	7.23 ± 1.26 (376)	6.46 ± 1.97 (336)	6.27 ± 2.0 (326)	6.27 ± 2.0 (326)
All patients with TL (SPT)	48	10.54 ± 2.47 (506)	10.48 ± 2.48 (503)	9.94 ± 2.88 (477)	6.83 ± 1.43 (328)	6.71 ± 1.52 (322)	5.96 ± 1.82 (286)	5.81 ± 1.76 (279)	5.46 ± 1.83 (262)	4.22 ± 1.85 (203)
All patients with TLP (SPT)	24	11.16 ± 1.34 (268)	11.08 ± 1.44 (266)	10.71 ± 1.81 (257)	7.29 ± 0.91 (175)	7.13 ± 0.99 (171)	6.08 ± 1.12 (146)	6.04 ± 1.12 (145)	5.75 ± 1.29 (138)	4.25 ± 1.65 (102)

Abbreviations: APT, active periodontal therapy; SD, standard deviation; SPT, supportive periodontal therapy; TL, tooth loss; TLP, periodontal tooth loss.

later. Here 73.9% of the privately insured participants showed a high educational status and 60.9% a marital status with partner. Statutory insured participants came to 57.4% for both. Unlike Pretzl et al not single marital status, but living with partner shows a positive correlation with TL, which may be due to different distributions of family status in the cohorts.[11] Further studies show correlations of marital status with tooth loss.[54,55] However, socioeconomic factors have already been described as robust factors for periodontitis and their impact on health is well known.[56,57] It has been shown several times that oral hygiene is influenced in the long term by socioeconomic factors in the early years.[58,59] This difference can also be obtained from the present data for an advanced age. The PCR differs approximately 10% between patients with private (26.7 ± 11.7%) and statutory (34.9 ± 13.7%) insurance. Socioeconomic factors in the present study could be translated to a late consequence of monetary and access options to preventive offers, which in the worst case may cause differences in tooth loss. In this study, 46 privately insured persons lost 48 teeth and 54 persons with statutory insurance lost 73 teeth.

To the best of our knowledge, the change of practitioner, even though strictly defined by a single change, and the number of SPTs takes into account two new factors in the regression analysis that have not been included in previous literature before. On one hand, the positive correlation between the change of practitioner and tooth loss could be due to the different experience and the possibly resulting different treatment consequences of the respective practitioner. This may be plausible, in particular against the background that during SPT also undergraduate and postgraduate students were involved in the treatment. Further, a new therapist may be likely to react more invasively to signs of disease (eg a single deep pocket or furcation lesion) than a therapist that sees a patient already for years and knows the stability of the situation. On the other hand, it must be self-critical noted that due to the structural contrariness in a university setting, it is not possible to permanently assign each patient to the same practitioner. In addition, the private insurance status of patients presents a potential confounder for the change of practitioner, as many privately insured patients are treated by dentists rather than by students.

The correlation of the number of SPTs with TL on first sight seems to contradict the correlation between lack of adherence and TL. Patients with TLP had on average almost six SPT appointments more over 10 years compared to patients without TLP (27.08 vs. 21.08 SPTs). Number of SPT on one hand indicates high effort in SPT, but on the other hand indicates high periodontal risk (PRA) encompassing established risk factors as, for example smoking and severe bone loss. It is not the simple number of SPTs that indicates effective maintenance. A low-risk patient adheres to maintenance attending SPT once a year (i.e. 10 SPTs in 10 years). A high-risk patient attending 20 SPTs in 10 years (twice the number) may not be adherent if she/he attends all recommended visits during the first 5 years and quits SPT thereafter.

In addition, in terms of overall TL, interleukin-1 polymorphism and the age at the start of therapy were identified as risk factors. This confirms results of previous studies.[6,11,13,15]

Some studies confirm associations between polymorphisms and periodontitis, but the majority of the studies fail.[60] Huynh-Ba et al (2007) consider in their systematic review 122 publications on composite polymorphism. According to the results of the meta-analysis, there is only insufficient evidence that a positive genotype contributes to the progression or treatment results of periodontitis. The main reasons are the too small study populations and the associated lack of statistical significance.[19] Therefore, and due to the complex

TABLE 5 Descriptive data for TL (overall and periodontal) according to categorical risk factors

Parameter		Overall patients [n]	TL		TLP	
			Overall [n]	Patient (mean ± SD)	Overall [n]	Patient (mean ± SD)
Gender	Male	52	56	1.17 ± 1.42	20	0.42 ± 0.77
	Female	48	64	1.23 ± 1.95	23	0.44 ± 1.02
Private insurance	Yes	46	56	1.22 ± 1.62	22	0.48 ± 0.86
	No	54	64	1.18 ± 1.79	21	0.39 ± 0.94
Change of practitioner	Yes	62	83	1.34 ± 1.89	24	0.39 ± 0.89
	No	38	37	0.97 ± 1.35	19	0.50 ± 0.92
Smoking (T2)	Active	9	13	1.44 ± 2.24	8	0.88 ± 1.69
	Former/never	91	107	1.18 ± 1.66	35	0.38 ± 0.79
SPT	Adherent	58	69	1.19 ± 1.76	30	0.52 ± 1.01
	Non-adherent	42	51	1.21 ± 1.65	13	0.31 ± 0.72
Diabetes	Yes	11	16	1.45 ± 2.16	8	0.73 ± 1.56
	No	89	104	1.17 ± 1.65	35	0.39 ± 0.79
Cardiovascular disease	Yes	30	27	0.90 ± 1.40	12	0.40 ± 0.81
	No	70	93	1.33 ± 1.82	31	0.44 ± 0.94
Interleukin-1 polymorphism	Positive	31	33	1.06 ± 1.57	6	0.19 ± 0.48
	Negative	69	87	1.26 ± 1.77	37	0.54 ± 1.02
Initial diagnosis	Moderate	21	19	0.90 ± 1.18	4	0.19 ± 0.40
	Severe	79	101	1.28 ± 1.82	39	0.49 ± 0.99
Marital status[a]	With partner	59	79	1.34 ± 1.53	27	0.46 ± 0.88
	Without partner	39	40	1.34 ± 1.53	16	0.41 ± 0.97
Educational status[a]	Low	33	47	1.42 ± 1.79	15	0.45 ± 0.97
	High	65	72	1.11 ± 1.69	27	0.42 ± 0.88

Abbreviations: SD, standard deviation; SPT, supportive periodontal therapy; TL, tooth loss.

[a]Two patients denied giving the according information.

inheritance and genetic background of periodontitis the representation of a single polymorphism as a risk factor for TL must be viewed with caution.

Furthermore, TLP correlated positively with cardiovascular diseases confirming earlier results regarding total TL. How is TLP linked to cardiovascular disease? Considering the association of cardiovascular with periodontal disease,[61-64] it may be that teeth with periodontal lesions are more likely to be extracted in cardiovascular diseased patients to lower the inflammatory load. On the other hand, drugs described due to cardiovascular disease (e.g. calcium channel blockers) may have increased periodontal risk in this respective subgroup.

The different examiners particularly at the beginning of APT, the lack of calibration for GBI and PCR, and partially self-reported reasons for tooth loss are a clear limitation of this study. In a university setting with dentists attending for postgraduate education and then leave university after 3 to 4 years of education, it cannot be guaranteed that all patients are cared for consistently over a period of 10 years by just one therapist. Even under a consistent treatment concept within the department of periodontology, different therapists to some extent cause variations of treatment decisions including extraction during APT. The cohort would probably have been more homogeneous with the same therapist. Furthermore, during SPT, some patients were treated by both periodontists and students under supervision, which may have affected the quality of treatment and its outcome.

5 | CONCLUSIONS

Taking into account all limitations of this study, the following conclusions may be drawn:

1. TL on average is a rare event, especially for periodontal reasons, over 10 years after completion of APT confirming the applied treatment concept.
2. Initial diagnosis, non-adherent SPT, current smoking status, marital and low educational status, private insurance, change of practitioner, BOP and number of SPT are identified as risk factors for both, TL and TLP over 10 years of SPT.
3. Risk-adopted allocation of SPT intervals could prevent TL(P).

TABLE 6 Poisson regression analysis: overall TL during SPT according to different risk factors

Parameter	Regression coefficient	95% CI		SD	*P*	Relative risk	95% CI		Lost teeth[a] [n]	Affected patients[a] [n]	TL/affected patient[a] [n]
		Lower limit	Upper limit				Lower limit	Upper limit			
Constant	-40.480	-42.991	-37.970	1.281	<.001	2.628	2.135	3.234			
Severe initial diagnosis	1.285	0.738	1.833	0.279	<.001	3.616	2.092	6.252	101	38	2.66
Non-adherent SPT	1.491	0.987	1.996	0.257	<.001	4.443	2.683	7.257	51	22	2.32
Smoking	1.754	1.037	2.471	0.366	<.001	5.778	2.820	11.840	13	5	2.60
Marital status (with partner)	2.542	2.054	3.030	0.249	<.001	12.702	7.797	20.693	79	33	2.39
Interleukin-1 polymorphism	1.210	0.723	1.697	0.249	<.001	3.353	2.060	5.458	33	13	2.54
Low educational status	0.544	0.063	1.024	0.245	.027	1.722	1.065	2.785	72	28	2.57
Private insurance	-1.121	-1.646	-0.595	0.268	<.001	0.326	0.193	0.551	56	21	2.67
Change of practitioner	1.585	1.018	2.151	0.289	<.001	4.878	2.768	8.596	83	32	2.59
Age (T0)	0.094	0.069	0.120	0.013	<.001	1.099	1.072	1.127			
BOP	0.062	0.033	0.091	0.015	<.001	1.064	1.033	1.095			
Number of SPT	0.152	0.114	0.190	0.019	<.001	1.164	1.121	1.209			

Note: Dependent variable: overall TL during SPT (n = 100)

Abbreviations: BOP, bleeding on probing; CI, confidence interval; SD, standard deviation; SPT, supportive periodontal therapy; TL, tooth loss.

[a]For metric parameters (BOP, age, number of SPT), this specification is not possible.

TABLE 7 Poisson regression analysis: periodontal TL during SPT according to different risk factors

Parameter	Regression coefficient	95% CI		SD	*P*	Relative risk	95% CI		Lost teeth[a] [n]	Affected patients[a] [n]	TLP/affected patient[a] [n]
		Lower limit	Upper limit				Lower limit	Upper limit			
Constant	-41.584	-44.607	-38.562	1.542	<.001	8.714	4.242	11.790			
Severe initial diagnosis	2.582	1.346	3.818	0.630	<.001	13.225	3.841	45.531	39	38	1.03
Non-adherent SPT	1.031	0.191	1.872	0.429	.016	2.804	1.210	6.499	13	22	0.59
Smoking	3.354	2.384	4.323	0.495	<.001	28.604	10.850	75.409	8	5	1.60
Marital status (with partner)	2.751	2.003	3.500	0.382	<.001	15.661	7.408	33.108	27	33	0.82
Cardiovascular disease	1.558	0.722	2.395	0.427	<.001	4.751	2.058	10.968	12	12	1.00
Low educational status	0.751	0.038	1.465	0.364	.039	2.119	1.038	4.326	27	28	0.96
Private insurance	-0.845	-1.664	-0.025	0.418	.043	0.430	0.189	0.975	22	21	1.05
Change of practitioner	2.265	1.352	3.178	0.466	<.001	9.634	3.866	24.005	24	32	0.75
BOP	0.078	0.022	0.134	0.029	.006	1.081	1.022	1.144			
Number of SPT	0.252	0.180	0.323	0.037	<.001	1.286	1.198	1.382			

Note: Dependent variable: TL due to periodontal reasons during SPT (n = 100)

Abbreviations: BOP, bleeding on probing; SD, standard deviation; SPT, supportive periodontal therapy; TLP, periodontal tooth loss.

[a]For metric parameters (BOP, number of SPT), this specification is not possible.

4. Additionally, interleukin-1 polymorphism and age at the beginning of therapy were identified as risk factors for total TL, whereas cardiovascular disease was identified as risk factor for TLP.

ACKNOWLEDGEMENTS

We dedicate this article to Dr Rita Arndt†, without whose long-term patient loyalty many study participants could not have been re-examined.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests related to this study. The study was self-funded by the authors and their institutions. Hain Lifescience GmbH (Nehren, Germany) supported analyses for IL-1 polymorphism.

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How to cite this article: Petsos H, Schacher B, Ramich T, et al. Retrospectively analysed tooth loss in periodontally compromised patients: Long-term results 10 years after active periodontal therapy—Patient-related outcomes. *J Periodont Res*. 2020;55:946–958. https://doi.org/10.1111/jre.12786