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Retrospective long-term analysis of tooth loss over 20 years in a specialist practice setting: Periodontally healthy/gingivitis and compromised patients

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Abstract

Objective: To assess tooth loss (TL) in initially periodontally healthy/gingivitis (PHG) and periodontally compromised (PC) individuals during a 15- to 25-year follow-up in a specialist practice and to identify the factors influencing TL.

Materials and methods: Patients were re-examined 240 ± 60 months after active periodontal therapy (PC) or initial examination (PHG). PHG patients were periodontally healthy or had gingivitis, and PC patients exhibited at least stage II periodontitis. TL, patient-related outcomes, and risk factors for TL were assessed at the patient level (group-relation, gender, age, smoking, bleeding on probing, educational status, mean number of visits/year).

Results: Fifty-six PC patients receiving regular supportive periodontal care (12 female, mean age 49.1 ± 10.9 years, stage II: 10, stage III/IV: 46) lost 38 teeth (0.03 ± 0.05 teeth/year). Fifty-one PHG patients (23 female, mean age 34.5 ± 12.4 years) following regular oral prevention lost 39 teeth (0.04 ± 0.05 teeth/year) ($p = .631$). Both PC and PHG groups did not show any significant differences regarding visual analogue scale measurements [aesthetics ($p = .309$), chewing function ($p = .362$), hygiene ($p = .989$)] and overall Oral Health Impact Profile ($p = .484$). Age at the start of follow-up was identified as a risk factor for TL ($p < .0001$).

Conclusion: PC and PHG patients exhibited similarly small TL rates over 240 ± 60 months, which should, however, be interpreted with caution in view of the group heterogeneity.

Clinical trial number: DRKS00018840 (URL: https://drks.de).

KEYWORDS

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

Clinical Relevance

Scientific rationale for study: Long-term tooth retention is the ultimate goal of dental therapy. This study provides information on tooth loss (TL) during 15–25 years of supportive periodontal therapy and oral prevention in periodontally compromised (PC) and periodontally healthy/gingivitis (PHG) patients.

Principal findings: Twenty years after active periodontal therapy/initial examination, 56 PC patients lost a similar small number of teeth ($n = 38$) compared to 51 PHG patients ($n = 39$) in a

specialist practice setting. PC patients were as satisfied as PHG patients regarding aesthetics, chewing function, hygiene, and overall OHIP mean sum score. Age at start of follow-up was identified as a risk factor for TL.

Practical implications: Over half of all patients examined (56.0%) did not lose any teeth over 20 years. A well-established treatment concept contributes to tooth retention and high levels of patient-related outcome measures in the long term.

1 | INTRODUCTION

In adults, periodontitis is a frequent reason for tooth loss (TL) (Oliver & Brown, 1993; Püllen et al., 2013). Systematic periodontal treatment can significantly decrease the risk of TL in periodontitis patients (Hirschfeld & Wasserman, 1978; Becker et al., 1979).

Systematic reviews (SRs) have evaluated TL after periodontal treatment in university and private practice settings (Chambrone et al., 2010; Trombelli et al., 2015; Helal et al., 2019). TL was comparably rare in both settings, ranging between 0.1 and 3.3 teeth/patient (mean TL 1.4 teeth) in practice-based studies and between 0.7 and 3.0 teeth/patient (mean TL 1.8 teeth) in university-based settings, even after 19 years of supportive periodontal care (SPC) (Chambrone et al., 2010). Helal et al. reported annual TL rates between 0.05 and 0.23 teeth/patient in practice-based studies and between 0.01 and 0.36 teeth/patient in university settings (Helal et al., 2019). Patient-related factors, such as smoking, age, diabetes, and irregular SPC (Chambrone et al., 2010; Lee et al., 2015; Helal et al., 2019), as well as tooth-related factors, such as initial bone loss, residual periodontal probing depths (PPD), tooth mobility, and furcation involvement (Helal et al., 2019), were identified as risk factors for TL.

Nevertheless, in general dental practice, poor confidence in and low perceived utility of periodontal therapy for severely compromised teeth is often documented (Zaher et al., 2007). Furthermore, a substantial number of teeth (with minor or no coronal destruction from caries or endodontic complications) are extracted at an attachment level of 50%–70%, indicating that the threshold for "periodontal" extractions is too low and undifferentiated (Splieth et al., 2002). Therefore, we put forward the following hypothesis: After active periodontal treatment [APT: steps 1–3 (Sanz et al., 2020)], periodontally compromised patients [PC, at least stage II periodontitis (Papapanou et al., 2018)] lose more teeth than periodontally healthy or gingivitis patients [PHG; (Chapple et al., 2018)] over a maintenance period of 15–25 years.

To our knowledge, no study has yet drawn a comparison between TL in a group of PC patients after APT and TL in a group of PHG patients treated preventively at the same dental office over such a long period.

2 | MATERIALS AND METHODS

2.1 | Patients

For this retrospective cohort study, all PHG and PC patients who had undergone oral prevention (OP)/SPC 240 ± 60 months in maintenance in a private practice (HT, Kanalstraße 14, 48,147 Münster, Germany) were identified and randomly invited (randomization whether to invite or not) to participate until at least 50 patients per group had been re-examined. Block randomization was carried out to obtain groups of approximately the same size. The list was compiled by HP, who was not employed in private practice. The patients were allocated to the respective groups by TJ, who, therefore, was not blinded to the group assignment of the study participants. All participants were re-examined between the 25 October 2019 and 20 February 2020.

PHG candidates were selected according to following inclusion criteria:

- At baseline (T0) ≥18 years
- Panoramic radiograph or full-mouth set of periapical radiographs at T0 (performed for caries detection or to control root-filled or crowned teeth)
- A non-contributary medical history at T0 [diseases or conditions that require antibiotic prophylaxis to prevent bacteraemia (e.g., endocarditis); medication that may induce gingival overgrowth (e.g., anticonvulsants, immunosuppressants)]
- Regular (at least once per year) OP during the follow-up period
- PPD ≤3 mm and radiographic distance of cemento-enamel junction (CEJ) and alveolar bone crest ≤2 mm at T0 (Hausmann et al., 1991)

A comparable number of PC patients were invited to participate in this study. They had to meet the following criteria:

- At baseline (T0) ≥18 years
- Panoramic radiograph or full-mouth set of periapical radiographs at T0
- A non-contributary medical history at T0 (equal to PHG)
- APT completed (T1) at least 15 years prior to the final examination (T2)
- Regular SPC (at least once per year) during the follow-up period
- PPD ≥4 mm and radiographic distance of CEJ and alveolar bone crest >2 mm at T0

The study was approved by the Institutional Review Board for Human Studies of the Medical Faculty of the Johann Wolfgang Goethe-University, Frankfurt, Germany (approval number 19-361), and registered in the German register for clinical trials (URL: https://drks.de; registration number: DRKS00018840). All patients were informed of the risks and benefits as well as the procedures of the study and gave written informed consent.

2.2 | Treatment

Three time points and the follow-up period were defined:

T0: Baseline (initial dental and periodontal examination) of PHG/PC patients

T1: Re-evaluation after completion of APT (non-surgical and, if required, surgical therapy) for PC patients

T2: Final re-examination 240 ± 60 months after T0/T1 of PHG/PC patients

Follow-up period: (i) PHG: T0–T2, (ii) PC: T1–T2.

PHG patients sought treatment at the dental practice for control of caries or replacement of missing teeth. Before treatment, all patients were individually instructed on effective plaque control. They were scheduled for a 6- to 12-month OP program according to their current plaque index [plaque control record, PCR (O'Leary et al., 1972)] scores (PCR ≤ 50%: 1×/year, PCR > 50%: 2×/year), which included re-motivation and re-instruction for effective plaque control, professional mechanical plaque removal (PMPR), and topical application of a fluoride gel.

PC patients received oral hygiene instructions and anti-infective therapy [subgingival instrumentation with and without adjunctive systemic antibiotics (amoxicillin 500 mg and metronidazole 400 mg 3×/day for 7 days; van Winkelhoff et al., 1989), re-evaluation, and flap surgery, if needed, to further reduce periodontal pocket depth (PPD)]. After APT, all patients were invited to join SPC according to the severity of their periodontal disease [former aggressive periodontitis (AgP) and severe chronic periodontitis (ChP): 2×/year (Armitage, 1999); all others: 1×/year] and the mean plaque index scores (PCR ≤ 50%: 1×/year, PCR > 50%: 2×/year)]. SPC encompassed OP (as mentioned for PHG patients). Furthermore, at least once a year, PPDs were measured at six sites per tooth. Sites with a PPD of ≥4 mm and bleeding on probing (BOP) were scaled subgingivally by a dentist (Eickholz et al., 2008). If a patient showed more than five to six sites with PPD >4 mm and BOP, an anti-infective retreatment was done at an additional appointment, which was carried out in the same way as the anti-infective therapy described above considering individual factors like patient age, presence of systemic diseases, and time of re-evaluation.

2.3 | Evaluation of patient charts

The following patient- and tooth-related parameters were assessed by evaluating the patient charts and questionnaires by one independent examiner (TJ):

- Medical history
- Self-reported smoking history, categorized as non-smokers (never smoked), former smokers (stopped smoking ≥5 years ago), or active smokers (stopped smoking <5 years ago or currently smoking) (Lang & Tonetti, 2003)
- Dental status
- Periodontal status: PPD, BOP at six sites per tooth, furcation involvement (Hamp et al., 1975), tooth mobility (Nyman et al., 1975), and PCR (O'Leary et al., 1972)
- Periodontal staging: Retrospectively, each PC received a baseline (T0) staging according to the 2018 classification (Papapanou et al., 2018). Staging was determined according to radiographic bone loss and maximum PPD. Other complexity factors, like furcation involvement, tooth mobility, or less than 20 remaining teeth, were considered for staging. The extent was determined by the percentage of teeth showing radiographic bone loss or a PPD ≥4 mm (Tonetti et al., 2018).
- Retrospectively, each PHG patient at T0 was classified as periodontally healthy (PPD ≤3 mm, distance of CEJ and alveolar bone crest ≤2 mm, and BOP <10%) or gingivitis patient (PPD ≤3 mm, distance of CEJ and alveolar bone crest ≤2 mm, and BOP ≥10%) (Chapple et al., 2018).
- Marital status: with or without partner.
- Self-reported educational status: low (9–10 years; primary school, intermediate secondary school, apprenticeship) or high (12–13 years; upper secondary education) (Pretzl et al., 2018).
- TL during APT and SPC: charts were searched for TL, comparing dental status at T0, T1, and T2.
- Tooth type: anterior, premolar, molar.
- Charts were scanned for TL and the following categories were defined: caries (unrestorable carious lesions), periodontal reasons [combination of progressive CAL, furcation involvement II/III (Hamp et al., 1975), and/or tooth mobility II/III (Nyman et al., 1975) according to Petsos et al. (2020)], root resorption (root resorptions causing tooth mobility), prosthetic rehabilitation (unusable as abutment tooth), endodontic problems (complications/perforations that could not be managed by a revision), and tooth fractures (trauma or vertical/horizontal root fractures of root canal filled teeth).
- At T2, all patients completed the German OHIP questionnaire (OHIP-G49) and were asked about their satisfaction with their dental aesthetics, chewing function, and hygiene ability using a visual analogue scale (VAS) (John et al., 2002).

2.4 | Statistical analysis

The data were entered in an Excel-based (Excel version 16.23, Microsoft Corporation, Redmond, WA, USA) data matrix (TJ). The patient was considered as a statistical unit, and TL was defined as the primary outcome variable, calculated by subtracting the final number of teeth from the number of teeth at the beginning of the follow-up period (PHG: T0–T2; PC: T1–T2). All other parameters were assessed as absolute or relative frequencies with mean ± SD descriptively and defined as secondary outcome variables.

Univariate analysis (Tables 1, 2, and 4) was performed for the nominal scaled (chi-squared test) and metric variables (Pearson's correlation coefficient).

TABLE 1 Patient-specific characteristics

	PHG ($n = 51$)		PC ($n = 56$)		p
	n	%	*n*	%	Value
Gender (female)	23	45	12	21	.009
Age at start of follow-up (years)	34.5 ± 12.4		49.1 ± 10.9		<.0001
Age at re-examination (years)	55.8 ± 14.0		69.2 ± 11.2		<.0001
Private insurance	26	51	28	50	.919
Smoking status					
Former; active smoker	10/5	29/10	4/1	7/2	.022
Non-smoker	35	69	51	91	
Diabetes	1	2	1	2	.947
Cardiovascular disease	4	8	8	14	.428
OP/SPC					
Duration [years]	21.2 ± 3.8		20.1 ± 3.3		.086
At least 1×/year	48	94	37	66	.002
At least 2×/year	3	6	18	32	
At least 3×/year	0	0	1	2	
Number	1710		2613		<.0001
Per patient	33.53 ± 11.19		46.66 ± 11.83		
Per patient/year	1.58 ± 0.49		2.34 ± 0.56		
Initial diagnosis					
Healthy	32	63	0	0	<.0001
Gingivitis	19	37	0	0	
Moderate (stage II)	0	0	10	18	
Severe (stage III/stage IV)	0	0	42/4	75/7	
BOP at start of follow-up (%)	13.0 ± 18.6		7.4 ± 8.4		.045
BOP at re-examination (%)	4.1 ± 5.6		6.3 ± 7.9		.103
Mean PCR during SPC/OP (%)	40.2 ± 12.1		36.0 ± 10.5		.056
Marital status					
With partner	41	80	36	64	.085
Without partner	10	20	19	36	
Educational status[a]					
Low	12	24	26	47	.011
High	39	76	29	53	

Abbreviations: BOP, bleeding on probing; OP, oral prevention; PC, periodontally compromised; PCR, plaque control record; PHG, periodontally healthy/gingivitis; SPC, supportive periodontal care.
[a]One patient in the SPC group declined to supply the information.

Poisson regression analysis was carried out based on a Poisson distribution of the dependent variable TL (Kolmogorov–Smirnov test, $p = .604$). The model (adjusted for the number of teeth per patient at start of follow-up, offset variable) was based on significant bivariate correlations between TL and the patient-specific variables, as well as the significant differences found in univariate comparisons for patient-specific variables between PHG and PC. Poisson regression analysis was performed to identify patient-related risk factors for TL over a maintenance period of 240 ± 60 months considering group relation (PHG/PC), gender, age, smoking status (active vs. former/non-smoker), BOP, and level of education at start of follow-up, as well as the mean number of OP/SPC per year. Initial diagnosis and PPD were excluded from the Poisson regression model because of expected collinearities with the group relation since initial diagnosis differed 100% between PHG and PC, and PPD in the PHG group exhibited only one category (≤3 mm; 100%). As a result, the independent variables "initial diagnosis" or "PPD" correlated with the independent variable "group relation", which, as a consequence, would not reveal possibly existing significance.

Third molars were excluded from data analysis. A significance level of .05 was assumed. All statistical analyses were performed with the software SPSS 24 (IBM, Chicago, IL, USA).

TABLE 2 Site-specific characteristics

	PHG ($n = 51$)		PC ($n = 56$)		
	n	%	*n*	%	*p* Value
Teeth					
At start of follow-up [*n*]	1359		1302		<.0001
(per patient)	(26.65 ± 1.81)		(23.25 ± 4.53)		
At re-examination [*n*]	1320		1264		<.0001
(per patient)	(25.88 ± 2.29)		(22.57 ± 5.18)		
Anteriors					
At start of follow-up [*n*]	608	44.7	611	46.9	<.0001
(per patient)	(11.92 ± 0.34)		(10.91 ± 2.0)		
At re-examination [*n*]	607	46.0	605	47.9	<.0001
(per patient)	(11.90 ± 0.36)		(10.80 ± 2.14)		
Premolars					
At start of follow-up [*n*]	381	28.0	385	29.6	.001
(per patient)	(7.47 ± 0.90)		(6.88 ± 1.51)		
At re-examination [*n*]	369	28.0	365	28.9	.003
(per patient)	(7.24 ± 1.09)		(6.52 ± 1.82)		
Molars					
At start of follow-up [*n*]	370	27.3	306	23.5	<.0001
(per patient)	(7.25 ± 1.20)		(5.46 ± 2.66)		
At re-examination [*n*]	344	26.0	294	23.3	<.0001
(per patient)	(6.75 ± 1.55)		(5.25 ± 2.68)		
PPD before APT [sites]					
≤3 mm		n/a		56.3 ± 22.4	
4–5 mm		n/a		35.0 ± 19.2	
≥6 mm		n/a		8.7 ± 9.2	
PPD at start of follow-up [sites]					
≤3 mm		100		85.3 ± 11.3	<.0001
4–5 mm		0		13.4 ± 10.3	<.0001
≥6 mm		0		1.3 ± 1.9	<.0001
Tooth loss APT					
Overall [*n*]	n/a		39		
(per patient)	n/a		(0.70 ± 1.40)		
Tooth loss during follow-up					
Overall [*n*]	39		38		0.631
(per patient)	(0.76 ± 1.16)		(0.68 ± 0.97)		
(per patient/year)	(0.03 ± 0.05)		(0.04 ± 0.05)		
Anteriors [*n*]	1	2.6	6	15.8	0.013
(per patient)	(0.02 ± 0.14)		(0.11 ± 0.49)		
Premolars [*n*]	12	30.7	20	52.6	0.044
(per patient)	(0.24 ± 0.51)		(0.36 ± 0.70)		
Molars [*n*]	26	66.7	12	31.6	0.002
(per patient)	(0.51 ± 1.07)		(0.21 ± 0.46)		
Periodontal reasons [*n*]	0		11		<0.0001
(per patient)			(0.20 ± 0.40)		

Abbreviations: APT, active periodontal therapy; PC, periodontally compromised; PHG, periodontally healthy/gingivitis; PPD, periodontal probing depths; n/a, no information because no active periodontal therapy was carried out in this group.

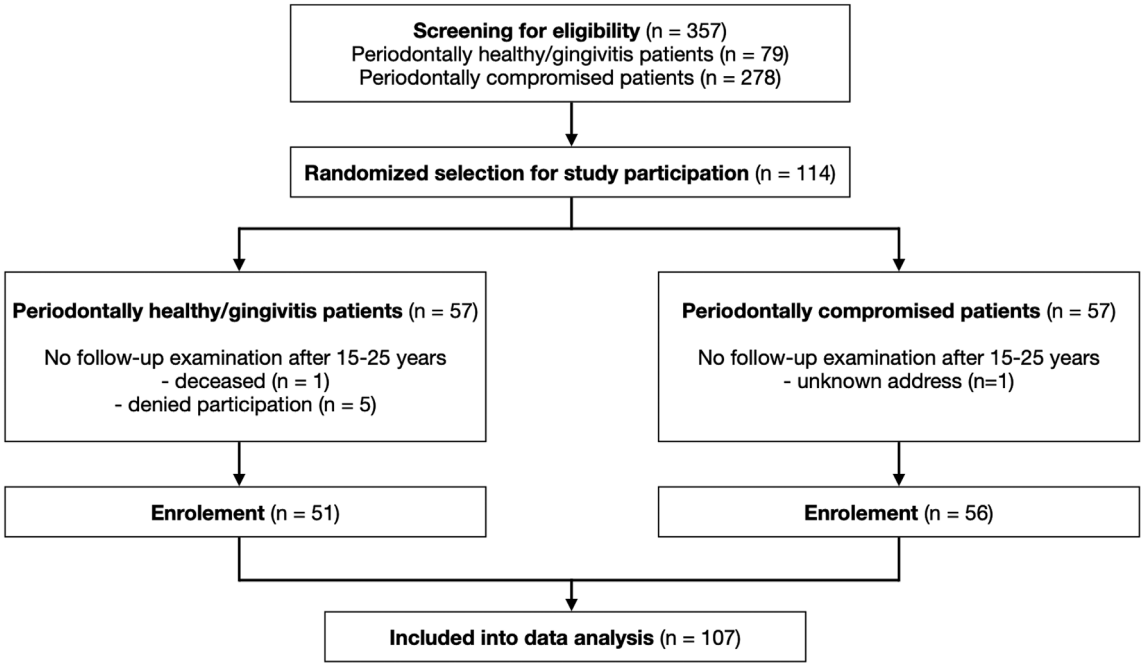

FIGURE 1 Patient flow diagram

TABLE 3 Reasons for TL during recall (categorized according to patient group)

Reason for TL	Caries	Periodontal	Endodontic	Fracture	Prosthetic	Root resorption	All	All subjects
PHG ($N = 51$)	14	0	17	5	1	2		39
PC								
Stage II ($n = 10$)	1	1	0	0	0	0	2	
Stage III ($n = 42$)	6	9	3	5	2	0	25	
Stage IV ($n = 4$)	3	1	3	2	2	0	11	
Total PC ($n = 56$)	10	11	6	7	4	0		38
All subjects	24	11	23	12	5	2		77

Abbreviations: *n*, number of patients; PC, periodontally compromised; PHG, periodontally healthy/gingivitis; TL, tooth loss.

3 | RESULTS

A total of 114 patients were initially invited to participate in this study. The final re-examination, after 15–25 years, was completed by 107 patients. One patient died, five patients refused to participate, and one patient could not be contacted (Figure 1).

Table 1 shows the patient-specific characteristics grouped for 51 PHG and 56 PC patients (after completion of APT) at the start of OP/SPC. There were 45% female PHG patients and 21% PC individuals ($p = 009$). The PHG candidates were significantly younger than the PC patients ($p < .0001$). There were significantly fewer non-smokers among PHG (69%) than among PC (91%) ($p = .022$). Both groups contained a diabetic patient (2%). In the PC group, there were twice as many with cardiovascular disease (14%) as in the PHG group (8%). BOP at the start of OP/SPC differed significantly ($p = .045$). With an average of 2.34 ± 0.56 visits per year, PC completed significantly more maintenance visits than PHG (1.58 ± 0.49; $p < .0001$). Twelve PHG patients reported low education, while 26 PC patients reported low education ($p = .011$). Sixteen PC patients (29%) received adjunctive systemic antibiotics during APT, and six (11%) received recurrent therapy during SPC.

Table 2 provides site-specific characteristics for all subjects. PHG started (T0) with significantly more teeth per patient (26.65 ± 1.81) than PC (T1), with a mean of 23.25 ± 4.53 teeth ($p < .0001$). The biggest difference was in molars (PHG: 7.25 ± 1.20; PC: 5.46 ± 2.66; $p < .0001$). While in the PHG group, there were no PPD ≥ 4 mm at the beginning of follow-up; in the PC group, this was reduced from 43.7% to 13.7% at the beginning of the follow-up period during APT. Table 3 provides the reasons for TL. PHG lost no teeth due to periodontal disease, but PC lost 11 teeth for this reason. PHG lost 17 teeth due to endodontic reasons, whereas PC lost only 6 teeth for these reasons. In general, more teeth were lost due to caries (24) and

TABLE 4 Patient reported outcome measures (PROMs)

	PHG ($n = 51$)	PC[a] ($n = 55$)	p Value
OHIP	12.04 ± 12.18	13.78 ± 15.59	.484
(median/range)	(8.0/ 0.0–46.0)	(9.0/ 0.0–70.0)	
VAS			
Aesthetic	77.88 ± 20.87	81.38 ± 18.57	.309
(median/range)	(85.0/ 20.0–100.0)	(89.0/ 9.0–100.0)	
Chewing function	89.88 ± 12.41	89.91 ± 11.29	.362
(median/range)	(94.0/ 49.0–100.0)	(92.0/ 44.0–100.0)	
Hygiene ability	82.71 ± 14.81	83.29 ± 15.33	.989
(median/range)	(85.0/ 40.0–100.0)	(90.0/ 30.0–100.0)	

Abbreviations: PHG, periodontally healthy/gingivitis; PC, periodontally compromised; OHIP, oral health impact profile, VAS, visual analogue scale.
[a]One patient in the SPC-group declined to supply the information.

TABLE 5 Poisson regression analysis: Tooth loss between T1 and T2 according to different risk factors

					95% CI for IRR	
Parameter	Regression coefficient	SE	p Value	Incidence rate ratio (IRR)	Lower limit	Upper limit
Constant	−30.764	0.852	<.0001	4.357E−14	8.204E−15	2.313E−13
Group relation (PHG)	0.177	0.339	.603	1.193	0.614	2.320
Gender (male)	−0.510	0.313	.103	1.079	0.325	1.109
Age at start of follow-up	0.082	0.013	<.0001	1.085	1.057	1.114
Smoking status (active smoker)	−0.599	0.399	.134	0.549	0.251	1.203
BOP at start of therapy	0.001	0.006	.823	1.001	0.990	1.013
Educational status (high)	−0.556	0.289	.054	0.573	0.326	1.009
Mean number of OP/SPC per year	0.288	0.298	.333	1.334	0.744	2.389

Note: Dependent variable: tooth loss during OP/SPC ($n = 106$); offset variable: number of teeth per patient at start of OP/SPC.
Abbreviations: BOP, bleeding on probing; CI, confidence interval; OP, oral prevention; PHG, periodontally healthy/gingivitis; SPC, supportive periodontal care.

endodontic (23) reasons than due to periodontal (11) reasons. PC did not lose more teeth (38) over the 20 years of SPC than PHG (39) lost over 20 years of OP ($p = .631$, Tables 2 and 3).

Table 4 reports patient-related outcome measures (PROMs). As one PC patient agreed to participate in this study but did not want to fill in the OHIP questionnaire, only 55 patients were included in the PC group for PROM analysis. There was no significant difference between PHG and PC in terms of the overall OHIP mean sum score (12.04 ± 12.18 vs. 13.78 ± 15.59). VAS values for aesthetics also failed to reveal a significant difference between PHG (77.88 ± 20.87) and PC (81.38 ± 18.57). Overall, these results show a high degree of satisfaction reported by PHG and older PC patients, without significant differences between these two groups (Table 4).

In addition to the significant differences between the PHG and PC groups (gender, age, smoking status, number of OP/SPC per year, initial diagnosis, mean BOP at T0, educational status) described in Table 1, significant bivariate correlations were found for TL and gender ($p = .021$), educational status ($p = .041$), and age at T0 ($p < .001$). Based on these findings, Poisson regression analysis (Table 5) identified age at start of therapy as risk factor for TL ($p < .0001$). The relation between TL and PHG/PC turned out to be insignificant ($p = .603$).

4 | DISCUSSION

In this study, we compared TL in PHG and PC over 15–25 years of regular OP/SPC. All subjects were treated in a specialized periodontal practice. Over the 15–25 years, 56 PC patients under regular SPC lost 38 teeth (0.04 ± 0.05 teeth/year) and 51 PHG patients under regular OP lost 39 teeth (0.03 ± 0.05 teeth/year) ($p = .631$). PC patients were as satisfied as PHG regarding aesthetics, chewing function, hygienic ability, and overall OHIP mean sum score. Age at start of follow-up was identified as a risk factor for TL. Over the 240 ± 60 months, PC and PHG groups lost a similarly small number of teeth.

PHG group had a mean age of 34.5 ± 12.4 years at start of follow-up, and PC group had a mean age of 49.1 ± 10.9 years. This difference in age is a limitation with regard to the comparability of the groups and may be regarded as a selection bias. Because age is a risk factor for TL (Pretzl et al., 2018), the lower age is an advantage for the

PHG group. Nevertheless, TL was comparable in both groups. A comparison of PHG and PC of the same age would be a challenging task, as periodontitis is a disease of older people (Jordan & Micheelis, 2016) but interesting for future research. Further, patient-related risk factors and disease-associated markers (smoking status, BOP, educational status) of both groups were distributed significantly differently at the beginning of follow-up. Matuliene et al. (2008) reported a mean BOP of ≥30% as a patient-related risk factor for TL, and therefore BOP can be neglected in both groups (PHG: 13.0%, PC: 7.4%). Active smoking and a high educational status presented significantly more frequently in the PHG group at the start of follow-up. It must be noted that the educational status of individual patients in some of the younger PHG individuals has not yet reached the final stage and may therefore be falsified. However, these factors are associated with an increased risk of TL after periodontal treatment (PC) (Kocher et al., 2005; Matuliene et al., 2008; Bäumer et al., 2011). In case of PHG, they probably contribute less to TL. The significantly different PPD at the beginning of the follow-up observation is a result of the inclusion criteria of the study. The reduction of sites with PPD ≥4 mm in PC from 43.7% to 13.7% and a mean BOP of 7.4% confirm the effectiveness of periodontal therapy.

Even though both groups started the follow-up with significantly different clinical and patient-specific conditions, they had one thing in common: both followed the recommendation of their dentist to present themselves at regular intervals. All patients in the PC group consistently had at least one more risk factor for TL than those in the PHG group—periodontitis. Regardless of the reason for TL, it was possible by using a type of recall visits adapted to the disease and plaque score (SPC) to keep TL in a group with a history of periodontitis over 240 ± 60 months as low as that of a group of patients who are periodontally healthy or show gingivitis. If APT is taken into account, total TL in the PC group is higher than in the PHG group. Nevertheless, PC patients remain periodontally compromised (mostly stage III or IV) and are therefore more susceptible to the consequences resulting from periodontal disease, such as increased loss of attachment and even TL during SPC than periodontally healthy or gingivitis patients during OP. After accomplishment of APT, future TL slowed down to the rate of PHGs by a structured SPC in a specialized dental practice. Nevertheless, the initially unbalanced distribution makes it difficult to compare both groups regarding the primary outcome (TL) in detail. One could assume that PC patients had already lost a large number of their teeth in the APT,

With a mean TL rate of 0.04 teeth/patient/year, a very small number of teeth were lost during SPC by PC compared to SRs on this topic. Trombelli et al. reported, in an SR on the long-term effect of PMPR on secondary prevention of periodontitis, a low TL rate of 0.09 ± 0.08 teeth/patient/year for studies with a follow-up between 12 and 14 years (Trombelli et al., 2015). Nevertheless, this TL rate is 2 times higher compared to the present findings, which is even more remarkable with regard to the twice as long follow-up period of the present study. However, three of four studies included in this SR considered only patients with severe periodontitis, while moderate diagnoses (18%) were also considered in the present study. Another SR including 20 studies on predictors for TL in periodontitis patients determined an average annual TL rate per patient of 0.12 teeth (Helal et al., 2019), which is 3 times higher than in the present study. These SRs consider studies from university and private practice settings. A putative reason for low TL rates in this study is the fact that subgingival instrumentation during APT and SPC was performed exclusively by dentists, that is, the practice owner and his partner dentists. Different from, for example, university settings with several different dentists that decide on extractions over long observation times, in this study the practice owner was in charge and able to realize his preventive concept accordingly. An additional SR on risk factors for TL in periodontitis reports a total TL of 9.5% and 6.8% due to periodontal reasons (Chambrone et al., 2010). The corresponding values for PC in this study are 2.9% and 0.8%, respectively. This difference is certainly due to the significantly higher number of cases in the SR with 1723 patients. Interestingly, the annual TL rate per patient of PC (0.04 ± 0.05 teeth) is comparable to the TL rate of PHG (0.03 ± 0.05 teeth/patient/year). Although the total number of teeth lost is the same in both groups, the lost teeth types were different and the losses were due to different reasons: PC lost fewer molars than PHG but more anteriors and premolars. Some possible explanations may be that molars were lost due to unsuccessful root canal treatments more frequently in PHG and that the PC group started the follow-up treatment with fewer molars compared with PHG. In general, in addition to the expected higher TL for periodontal reasons in the PC group, an increased TL for carious and endodontic reasons would also be expected since the loss of attachment that occurs during periodontitis often results in exposed, rough root surfaces. These are per se more prone to caries than covered root surfaces (Hayes et al., 2016). Plausibly, the higher mean number of SPCs in PC reduced the number of caries, especially in the molar region.

The efficacy of the applied maintenance therapy becomes clear when comparing the number of teeth in each group at the end of follow-up with that of the corresponding age group in a population-representative cross-sectional study in Germany (Jordan & Micheelis, 2016). PC patients at the end of the study were on average 69.2 years old having 22.6 teeth. The 65- to 74-year-olds in the German cross-sectional study had 19.3 teeth left. PHG patients were 55.8 years old and had 25.9 teeth compared to 22.7 teeth as the mean value between the groups of 35- to 44- and 65- to 74-year-old patients in the cross-sectional study (Nitschke & Stark, 2016). Both groups in the present study had about three more teeth compared to the respective age group.

Thirty-two PC (57%) and 28 PHG (55%) patients did not lose any teeth during the 15–25 years of SPC/OP. With more than half of all patients in both groups not losing any teeth, not only is the overall TL comparable for PC and PHG but also is the rate of patients without TL. It is important to mention that PC patients suffering from periodontitis stage II (10/18%) only lost 2 teeth (0.2 per patient), while PC patients exhibiting stage III (42) lost 25 teeth (0.6 per patient), and patients with periodontitis stage IV (4) lost 11 teeth (2.75 per patient). The more severe the periodontitis, the more the number of teeth lost. Even though the number of teeth lost by PHG (39) and PC (38) groups

is very similar, and no correlation between the groups and the TL could be found, it can be noted that the effort required to achieve this result for PC patients was significantly higher, with on average 2.34 ± 0.56 SPCs/year, than for PHG patients, who received 1.58 ± 0.49 OPs/year. Nevertheless, patient distribution with regard to SPC frequency is unbalanced at the beginning of the follow-up period, so that a larger sample size would be necessary in order to be able to draw more well-founded conclusions from the SPC frequency to TL.

It is often assumed that PC patients are less satisfied with their dental/oral situation than patients who do not suffer from periodontitis. Patient-related outcome measures scored in this study could not confirm this assumption. The overall OHIP mean sum scores of 12.04 ± 12.18 for PHG patients and 13.78 ± 15.59 for PC patients show a very high degree of satisfaction in contrast with other reports of 24.9 for AgP (Bäumer et al., 2018) and 18.9 for ChP (El Sayed et al., 2019). The follow-up period in the present study is about twice as long as the AgP study and has on average the same follow-up as the ChP study. However, it is unclear to what extent the length of the observation has an influence on the OHIP value. Even if the results after 20 years in both groups do not show any significant differences, it should be kept in mind that PCs show significantly higher OHIP values before therapy than PHGs. This was shown by another study in which periodontitis patients had a pre-therapeutic OHIP mean sum score (OHIP-49) of 48.6 and periodontally affected patients (PPD ≤3 mm and mean BOP 11%) 36.8 ($p < .01$) (Durham et al., 2013). Subgingival instrumentation with or without adjunctive systemic antibiotics resulted in substantial improvement of clinical parameters and OHIP (baseline: placebo 39.2 ± 27.2/antibiotics 46.0 ± 33.8; 2 years after treatment: placebo 32.2 ± 29.4/antibiotics 32.9 ± 29.4) (Harks et al., 2015). The impact of untreated periodontitis on the OHIP value was confirmed in a recently published SR, which indicated a 3.5-fold higher probability of deterioration in the OHIP value (OHIP-14) (Paśnik-Chwalik & Konopka, 2020). Nevertheless, another SR confirmed the effectiveness of non-surgical periodontal therapy on improvement in the OHIP values (Khan et al., 2021).

VAS score measurements confirmed these high degrees of satisfaction, which were furthermore similar between the groups. The very similar judgement of PHG and PC groups with respect to oral-health-related quality of life (OHrQL) may be explained by the difference in age. PHG patients were, on average, 14 years younger than PC patients. Expectations regarding OHrQL may decrease with age. This may also explain why AgP patients reported high OHIP scores, representing less satisfaction with OHrQL (Bäumer et al., 2018).

PC patients lost 22 teeth if SPC was performed once a year, 16 teeth if performed twice a year, and no teeth if performed three times a year. Interestingly, the more frequent the SPC, the more effective it is in conserving anteriors and molars than premolars. This was underlined by the finding that premolars were lost most frequently during SPC in PC. Premolars have the highest prevalence of infrabony defects, and furcation closure by regenerative treatment is rarely achieved (Proestakis et al., 1992). In contrast to the findings in the present study, other studies have identified molars to be at higher risk for TL in AgP and ChP (Faggion et al., 2007; Muzzi et al., 2006; Pretzl et al., 2008; Bäumer et al., 2011, 2020). PHG patients lost 37 teeth if OP was performed once a year and 2 teeth if OP was performed twice a year. In PHG patients, a more frequent schedule seemed to be more effective in conserving anteriors and premolars. This was underlined by the finding that molars were lost most frequently by PHG patients during the observation time. In summary, this showed that although both groups lost a comparable number of teeth over the 15–25 years of OP/SPC, different tooth types were lost by PHG and PC groups.

TL according to perceived number of SPCs per year showed that PC patients having two SPCs per year did not lose more than three teeth, and patients with three SPCs per year did not lose a single tooth during SPC. In this practice-based analysis, 57.1% of PC patients did not lose any teeth during SPC, which is in line with an SR reporting rates between 50.0% and 88.5% (Chambrone et al., 2010). In the present study, 41.1% of the patients lost 1–3 teeth and 1.8% lost 4 teeth (0.04 teeth/patient/year). These values are low compared to a university-based study with 20 years of SPC, which reported TL in PC of 0.14 teeth/patient/year, with 27.1% not losing a single tooth, 40.0% losing 1–3 teeth, and 28.65% losing 4–9 teeth (Pretzl et al., 2018). However, the difference may be explained by the different severity of the included cases and by the university setting with more different therapists and a less stringent treatment protocol. TL of PC patients was comparable to the TL of PHG patients: If at least two OPs were realized per year, PHG patients did not lose more than one tooth during the follow-up: 54.1% of PHG patients did not lose any teeth, 43.2% lost 1–3 teeth, and 2.7% (one person) lost 6 teeth during follow-up. To the best of our knowledge, this is the first practice-based analysis reporting similar TL and OHrQL after 15–25 years of SPC in PC patients compared to TL during 15–25 years of OP.

As a limitation of this study, it should be mentioned that a more balanced distribution of risk factors of age, smoking, BOP, and educational status at the beginning of the follow-up period (group heterogeneity), resulting from the retrospective character of this study, might have led to different findings and reduced bias. However, multivariate analysis may adjust for this to some extent but not completely for the main confounding factors such as age and smoking. Additionally, SPC/OP have been characterized in terms of annual frequency of sessions. However, other aspects that may be of the same relevance (e.g., quantity, adherence to the suggested SPC program) have not been taken into consideration. The 20 years of observation and the private practice setting is the strength, whereas the retrospective character is a limitation of this analysis. Of course, a prospective study would have been able to better control for different factors. However, a prospective study over 20 years in a private practice setting is a daunting task.

5 | CONCLUSION

Over 15–25 years of SPC in a specialized dental practice PC patients lost a small number of teeth, which was comparable to PHG patients

over the same period of OP. Furthermore, PC patients were as satisfied as PHG patients with their dental situation. However, owing to the limitations described, these conclusions should be interpreted with caution.

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CONFLICT OF INTEREST

The authors declare no conflict of interests.

ETHICS STATEMENT

The Institutional Review Board for Human Studies of the Medical Faculty of the Johann Wolfgang Goethe-University (Frankfurt, Germany) approved all assessments (approval number 19-361), and informed consent was obtained from each participants. The study was conducted following the Declaration of Helsinki.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to the interpretation of the data for the work, and also to drafting and critically revising the manuscript. They gave their final approval of the version to be published and agreed to be accountable for all aspects of the work. Additionally, Heinz Topoll, Peter Eickholz, and Hari Petsos conceived the ideas for concept and design of the study; Timo Junge collected the data; Peter Eickholz and Heinz Topoll complied methodical approaches; Hari Petsos analysed data and managed the group; Timo Junge led the writing.

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