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Tooth loss in periodontally treated patients: A registry- and observation-based analysis

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Abstract

Aim: According to retrospective clinical studies, periodontal treatment retains teeth. However, evidence on the effectivity of periodontal treatment stemming from the general population is lacking.

Materials and Methods: We analysed data of periodontally treated patients from routine data of a major German national health insurance (BARMER-MV; sub-sample of the Federal State of Mecklenburg-Vorpommern) and from a clinical cohort (Greifswald Approach to Individualized Medicine, GANI_MED), as well as periodontally untreated and treated participants of the Study of Health in Pomerania (SHIP-TREND) with either ≥2 or ≥4 teeth with pocket depths ≥4 mm. Yearly tooth loss (YTL) estimates and incidence rates were evaluated.

Results: For moderately to severely affected groups, YTL and incidence rates were higher in BARMER-MV patients (0.35 and 0.18, respectively) than in untreated SHIP-TREND controls (0.19 and 0.08, respectively). In line, treated SHIP-TREND participants exhibited higher YTL rates than untreated SHIP-TREND controls (0.26 vs. 0.19). For severely affected groups, results with respect to tooth loss were inconclusive regarding the beneficial effects of periodontal treatment conducted either in the university (GANI_MED data) or in the general practice.

Conclusion: Until 2021, periodontal treatment performed in German general dental practices within the national health insurance system was probably not efficient in retaining more teeth in the short- to mid-term. Since reimbursement schemes were changed in 2021 and now cover periodontal treatment to a much larger extent, the future will show whether these new reimbursement codes will improve the quality of periodontal treatment and whether they will lead to more long-term tooth retainment.

KEYWORDS
periodontal diseases, periodontal treatment, registry-based analysis, tooth loss

Michael Raedel and Michael H. Walter contributed equally to this study.

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Clinical Relevance

Scientific rationale for study: To find out whether periodontal treatment retains more teeth compared with no periodontal treatment, we compared tooth loss data from periodontally treated patients (BARMER-MV) with untreated, periodontally diseased controls selected from SHIP-TREND.

Principal findings: Treated BARMER-MV patients had notably higher tooth loss rates than untreated SHIP-TREND participants with moderate to severe periodontitis.

Practical implications: In the short- or mid-term, periodontal treatment was not efficient with regard to YTL and incidence rates on a population level in German patients. Thus, improvements in the diagnosis, treatment planning and treatment of periodontitis, are necessary in the general dental practice.

1 | INTRODUCTION

The primary goal of systematic periodontal treatment is to eliminate the infection by removing microbial deposits to prevent further attachment loss. After the active periodontal treatment (APT) phase, patients are offered a lifelong supportive periodontal therapy (SPT). The concept of ongoing maintenance is considered as a requirement for favourable periodontal treatment outcomes and it is based on institutional university trials and on specialist-based studies in various parts of the world. However, scientific literature does not provide sufficient information about tooth retention as one outcome of periodontal therapy (Loos & Needleman, 2020). Cochrane reviews concluded that periodontal treatment efficacy could only be determined for surrogate variables but not for tooth loss (Lamont et al., 2018; Worthington et al., 2019).

Patient preferences are becoming increasingly important for decision-making in health care systems. According to a comprehensive conjoint analysis of 267 periodontally affected patients, avoiding tooth loss is the main reason for a treatment decision, whereas avoiding gum recessions or hypersensitivity or out-of-pocket payments are of smaller importance (Scheibler et al., 2016). Thus, from a patient's perspective, tooth retention is the most prominent periodontal treatment result.

Recently, we compared treatment results from four German university centres, and we found comparably low tooth loss rates despite different treatment philosophies (Graetz et al., 2020). However, studies showing that periodontally treated patients suffer from less tooth loss than their periodontally diseased but untreated counterparts are currently missing (Smiley et al., 2015). Since tooth loss is a rare event, such a study would necessitate a large number of patients and a long follow-up time.

A recent paper sparked enormous discussions in Germany (Raedel et al., 2019). Analyses of an insurance registry showed that patients treated for periodontitis had higher tooth loss rates than untreated controls up to 4 years after treatment. German periodontists argued that the periodontal condition of the control group was unknown and that the control group may have constituted mostly of periodontally healthy subjects. Since no clinical findings were available for these registry data, no definitive conclusions could be drawn. Population-wide data, which assess the efficiency of the periodontal therapy while providing also comprehensive clinical data, are currently missing. To our knowledge, there are currently no real-world scenario data available with tooth loss as an endpoint of periodontal treatment worldwide (Lamont et al., 2018).

We want to reduce this knowledge gap with German data. Until 1st July 2021, German statutory health insurance only reimbursed APT. Since <1% of teeth received surgical treatment within the German statutory insurance, we replaced the term APT with non-surgical periodontal treatment (NSPT). Furthermore, it is unclear if at all or to what extent measures performed after NSPT reflect a *lege artis* performed SPT session. Therefore, we used the term post-periodontal treatment (POST-TX) instead of SPT.

Thus, we jointly evaluated data from periodontally treated patients contained in the statutory insurance database BARMER, untreated and treated groups from the population-based longitudinal Study of Health in Pomerania (SHIP-TREND), and periodontally treated patients of the Unit of Periodontology, University Medicine Greifswald, thereby providing clinical information about the results of *lege artis* performed periodontal treatment. Since the BARMER data did not contain any clinical data, we used clinical information from periodontally diseased SHIP-TREND participants, who reported periodontal treatment, to infer their periodontal status and tooth loss rate as a community treated group. All studies were drawn from the same catchment area, but with different dental information. We aimed to find out whether (i) at the population level, periodontal treatment reduces the risk of tooth loss as compared with no periodontal treatment, (ii) periodontal treatment retains more teeth when conducted in a university setting as opposed to a general dental practice, and (iii) extraction patterns differ between NSPT and POST-TX. Only a joint overview of all dental information allows us to judge a potential benefit of a periodontal treatment in the general population.

2 | MATERIALS AND METHODS

A detailed description of the BARMER routine data, SHIP-TREND, GANI_MED and administrative requirements for periodontal treatment in Germany is provided in the Online Supplement. Within German statutory insurance regulations, teeth exhibiting at least one site

with pocket probing depth (PPD) ≥3.5 mm are eligible for NSPT (Gemeinsamer Bundesausschuss, 2006).

We compared the following groups with 10,429 periodontally treated patients from the BARMER-MV routine data: (i) periodontally untreated SHIP-TREND participants (age 35–74 years, no self-reported periodontal treatment during 5 years before SHIP-TREND-0 and between SHIP-TREND-0 and SHIP-TREND-1) assigned to two control groups—one with ≥2 ($N = 615$) and one with ≥4 teeth with PPD ≥4 mm ($N = 354$); (ii) periodontally treated SHIP-TREND participants aged 35–74 years with self-reported periodontal treatment between SHIP-TREND-0 and SHIP-TREND-1, but without any self-reported periodontal treatment within 5 years before SHIP-TREND-0, either with ≥2 ($N = 797$) or ≥4 teeth ($N = 479$) with PPD ≥4 mm; (iii) periodontally treated patients from the Unit of Periodontology, University Medicine Greifswald (GANI_MED project), aged 35–74 years ($N = 254$). Information on dental history including periodontal and dental status, as well as periodontal treatment, was retrieved from the patients' charts.

2.1 | Statistical analyses

The BARMER-MV database only provided information on the number of presumably periodontally treated teeth, claimed according to statutory insurance regulations, but not on the total number of present teeth. Here, we assumed that for BARMER-MV patients, the number of periodontally treated teeth equals the total number of present teeth, knowing that the total number of teeth was underestimated. Based on sex- and age-specific numbers of periodontally treated teeth derived from the BARMER-MV database (see Appendix Table 1), untreated SHIP-TREND controls were selected such that the number of teeth lied within intervals defined as (mean ± 2 × SD) based on BARMER-MV data. Accordingly, 615 and 354 SHIP-TREND participants with ≥2 and ≥4 teeth, respectively, with a maximum PPD (per tooth) of ≥4 mm were selected as periodontally untreated controls. It should be noticed that the number of affected teeth in SHIP-Trend participants is based on a half-mouth protocol. Thus, projected to a full-mouth with a six-site protocol, at least four or eight teeth were periodontally affected. Average numbers of teeth in SHIP-TREND-0 controls were higher compared with numbers of periodontally treated teeth calculated for BARMER-MV patients because in the insurance claim data, only teeth with a maximum PPD of ≥4 mm were included, as for those teeth periodontal treatment was applied for (Appendix Table 1).

For SHIP-TREND-0 subjects with at least one extraction event (≥1 extraction), event time was set to be half the follow-up time between SHIP-TREND-0 and SHIP-TREND-1 (exact extraction time was unknown). Accordingly, for GANI_MED patients with at least one extraction event, event times were set to half the NSPT length, if extraction occurred during NSPT, or to NSPT length plus half POST-TX length, if extraction occurred during POST-TX. For GANI_MED patients, the number of teeth was counted excluding third molars at the start of NSPT, start of POST-TX and the final examination. For BARMER-MV patient data, the time period was split into two intervals, representing NSPT and the presumed period after the settlement of treatment costs (herein referred to as POST-TX), respectively: [−1; +0.5 years] and [+0.5; +4 years].

For continuous data, means, SDs, medians, and 25% and 75% quantiles were shown. Distributions of categorical data were presented in numbers and percentages. Distributional differences were analysed using either Mann–Whitney *U* tests or Chi-squared tests.

We analysed three measures to characterize tooth loss within BARMER-MV patients, SHIP-TREND participants and GANI_MED patients. First, yearly tooth loss (YTL) estimates were determined as the quotient between the number of extracted teeth per patient and follow-up time, in exact years, with bias-corrected and accelerated bootstrap intervals (Poi & StataCorp, 2004). Differences in YTL estimates between groups were tested via Mann–Whitney *U* tests. Second, incidence rates defined as the number of subjects with at least one tooth extraction divided by person-years (95% confidence intervals [CIs] were calculated assuming constant hazard rates) were calculated. For both BARMER-MV and GANI_MED patients, the above-mentioned calculations were repeated with differentiation between NSPT and POST-TX. Comparisons of incidence rates between groups were made via mid *p*-values for tests of incidence rate difference. Third, the total number of tooth extractions per 1000 persons per week (with precise consideration of failure times) was graphically evaluated for BARMER-MV patients by adding a discrete symmetric normalized smoothing kernel (Daniell kernels; dimension 3). For untreated SHIP-TREND groups and GANI_MED patients, information on the average number of tooth extractions per 1000 persons per week was added.

Negative binomial regression models estimated the effects of self-reported periodontal treatment on the number of extracted teeth during 7-year follow-up of SHIP-TREND. Models were adjusted for age (modelled as restricted cubic splines with three knots), sex, smoking, education and known or diagnosed diabetes, and logarithmical follow-up time (as offset variable). Incidence rate ratios (IRR) with 95%CI were reported.

We completely renounced from statistical testing for comparisons with BARMER-MV patients because it was not possible to merge the registry data with either SHIP-TREND or GANI_MED. Statements on statistical significance were derived from comparison of CIs: if CIs did not overlap, statistical significance was deduced. All analyses were conducted with Stata/SE 17.0 (StataCorp, 2021) and R 4.0.3 (http://www.r-project.org).

3 | RESULTS

3.1 | Characteristics of study groups

Mean follow-up times were 3.1 and 6.7 years for treated BARMER-MV and GANI_MED patients, respectively, and about 7.4 years for

TABLE 1 Characteristics of periodontally treated patients from the BARMER-MV database, SHIP-TREND periodontally untreated and treated controls (either with ≥2 or ≥4 teeth with pocket probing depths (PPDs) ≥4 mm; half-mouth protocol with four sites) and GANI_MED long-term maintenance patients

		SHIP-TREND participants with ≥2 teeth with PPD ≥4 mm		SHIP-TREND participants with ≥4 teeth with PPD ≥4 mm		
	BARMER-MV patients	Periodontally untreated	Periodontally treated	Periodontally untreated	Periodontally treated	GANI_MED long-term maintenance patients
Study period	2011–2015	2008–2019	2008–2019	2008–2019	2008–2019	1993–2014
N	10,429	615	154	354	116	253
Total follow-up time, years	3.1 ± 1.1	7.4 ± 0.6	7.5 ± 0.6	7.3 ± 0.5	7.5 ± 0.7	6.7 ± 4.6
	3.1 (2.1; 4.0)	7.3 (7.1; 7.5)	7.3 (7.1; 7.5)	7.3 (7.1; 7.5)*	7.3 (7.1; 7.5)*	5.5 (2.7; 10.6)
Age, years	56.8 ± 9.6	53.5 ± 10.9	52.5 ± 9.3	53.8 ± 11.0	52.9 ± 9.0	57.0 ± 9.2
	57 (50; 64)	54 (44; 62)	53 (45; 59)	54 (44; 63)*	53 (47; 59)*	56.7 (49.8; 64.4)
Sex						
Female	6683 (64.1%)	264 (42.9%)	78 (50.7%)	139 (39.3%)	50 (43.1%)	136 (53.8%)
Male	3746 (35.9%)	351 (57.1%)	76 (49.3%)	215 (60.7%)*	66 (56.9%)	117 (46.2%)
Regular dental visits[a]						
No	356 (3.4%)	58 (9.4%)	12 (7.8%)	37 (10.5%)	7 (6.0%)	3 (1.2%)
Yes	10,073 (96.6%)	557 (90.6%)	142 (92.2%)	317 (89.5%)*	109 (94.0%)*	250 (98.8%)
Yearly professional tooth cleaning, yes	—	142 (23.1%)	46 (29.9%)	81 (22.9%)	34 (29.3%)	
Number of teeth (max. 32)	—	23.6 ± 5.7	24.0 ± 5.2	23.5 ± 5.6	24.2 ± 5.0	23.5 ± 3.9
		25 (21; 28)	26 (21; 28)	25 (20; 27)	26 (21; 28)	24 (21; 27)[b]
Number of teeth with PPD ≥4 mm (max. 28)	20.3 ± 6.4	4.7 ± 2.7	6.2 ± 3.3	6.4 ± 2.3	7.4 ± 2.9	17.3 ± 5.6
	21 (16; 25)	4 (3; 6)	6 (4; 8)**	6 (4; 8)*	7 (5; 10)*,**	18 (13; 22)
Subjects without extraction	6.235 (59.8%)	328 (53.3%)	70 (45.5%)	166 (46.9%)	50 (43.1%)	112 (44.3%)
Number of extracted teeth	1.0 ± 2.0	1.4 ± 2.7	2.0 ± 3.2	1.9 ± 3.2	2.2 ± 3.5	1.5 ± 2.2
	0 (0; 1)	0 (0; 2)	1 (0; 2)**	1 (0; 2)	1 (0; 3)	1 (0; 2)
Mean PPD, mm	NA	2.73 ± 0.55	2.97 ± 0.65	2.96 ± 0.57	3.12 ± 0.62	3.58 ± 0.82
		2.60 (2.38; 2.93)	2.79 (2.50; 3.38)**	2.78 (2.58; 3.20)	2.95 (2.63; 3.49)**	3.45 (3.00; 4.00)[c]
Mean CAL, mm	NA	2.75 ± 1.54	3.07 ± 1.35	3.14 ± 1.60	3.36 ± 1.35	NA
		2.47 (1.75; 3.50)	2.89 (2.22; 3.83)**	2.83 (2.10; 3.93)	3.25 (2.53; 3.83)**	

Note: Data are presented as *N* (%) or mean ± SD and median (25%; 75% quantile).
Abbreviations: CAL, clinical attachment loss; NA, not available.
[a]For BARMER-MV: yes, if the yearly average number of dental visits over the complete observation period was ≥1 (equalling at least one dental visit per year); for SHIP-TREND and GANI_MED: at least one dental visit within the last 12 months.
[b]Based on a maximum of 28 teeth.
[c]Based on a full-mouth protocol with six sites.
*$p < .05$ for comparison between untreated or treated SHIP-TREND participants with ≥4 teeth with PPD ≥4 mm and GANI_MED patients (except for number of teeth and mean PPD due to different recording protocols). **$p < .05$ for comparison between untreated and treated SHIP-TREND participants. Either Mann–Whitney *U* tests or Chi-squared tests were applied.

untreated and treated SHIP-TREND participants (Table 1). Both patient groups were on average 3–4 years older than SHIP-TREND groups and had about 3–4 times more teeth with PPD ≥4 mm than the SHIP-TREND groups. The percentage of participants without any tooth extractions was highest for BARMER-MV patients (59.8%) and lowest for periodontally treated SHIP-TREND participants with ≥4 affected teeth.

3.2 | Tooth loss in BARMER-MV patients compared with moderately to severely affected SHIP-TREND groups

We first focus on moderately to severely affected groups, that is, BARMER-MV patients and periodontally untreated and treated SHIP-TREND participants with ≥2 affected teeth (Table 2, left part). YTL

TABLE 2 Overview on yearly tooth loss and incidence rates for BARMER-MV patients, periodontally untreated and treated SHIP-TREND participants (with either ≥2 or ≥4 teeth with pocket probing depths (PPDs) ≥4 mm; half-mouth protocol with four sites) and GANI_MED long-term maintenance patients

	BARMER-MV patients		SHIP-TREND participants with ≥2 teeth with PPD ≥4 mm				SHIP-TREND participants with ≥4 teeth with PPD ≥4 mm				GANI_MED long-term maintenance patients	
			Periodontally untreated		Periodontally treated		Periodontally untreated		Periodontally treated			
	N	Estimates	*N*	Estimates	*N*	Estimates	*N*	Estimates	*N*	Estimates	*N*	Estimates
Yearly tooth loss rates (mean ± SD, 95% CI)												
NSPT	10,429	0.45 ± 1.10 (0.43–0.47)	NA	NA	NA	NA	NA	NA	NA	NA	253	0.69 ± 1.83 (0.47–0.91)
POST-TX	5510	0.23 ± 0.55 (0.22–0.25)	NA	NA	NA	NA	NA	NA	NA	NA	253	0.21 ± 0.58 (0.14–0.28)
NSPT and POST-TX or complete observation time	10,429	0.35 ± 0.75 (0.34–0.37)	615	0.19 ± 0.36 (0.16–0.22)	154	0.26 ± 0.42 (0.19–0.33)**	354	0.26 ± 0.42 (0.21–0.30)	116	0.29 ± 0.45 (0.21–0.37)	253	0.34 ± 0.68 (0.26–0.43)
Incidence rates (point estimate with 95% CI)[a]												
NSPT	10,429	0.23 (0.22–0.23)	NA	NA	NA	NA	NA	NA	NA	NA	253	0.25 (0.20–0.31)
POST-TX	5510	0.17 (0.16–0.18)	NA	NA	NA	NA	NA	NA	NA	NA	253	0.07 (0.06–0.08)
NSPT and POST-TX	10,429	0.18 (0.17–0.18)	615	0.08 (0.07–0.09)	154	0.10 (0.08–0.12)	354	0.10 (0.09–0.11)*	116	0.11 (0.08–0.14)*	253	0.15 (0.13–0.18)

Abbreviations: CI, confidence interval; NA, not available; NSPT, non-surgical periodontal treatment; POST-TX, post-periodontal treatment phase.

[a]For SHIP-TREND participants with at least one extraction event, event times were set to half the follow-up time between SHIP-TREND-0 and SHIP-TREND-1. For GANI_MED patients with at least one extraction event, event times were set to half the NSPT length, if extraction occurred during NSPT, or to NSPT length plus half POST-TX length, if extraction occurred during POST-TX.

*$p < .05$ for comparison with GANI_MED patients. **$p < .05$ for comparison between untreated and treated SHIP-TREND participants.

was notably higher in BARMER-MV patients (0.35, 95% CI: 0.34–0.37) compared with untreated SHIP-TREND controls (0.19, 95% CI: 0.16–0.22), while treated SHIP-TREND participants (0.26, 95% CI: 0.19–0.33) ranged in the middle. In line, incidence rates (for detailed information see Appendix Table 2) were highest in BARMER-MV patients (0.18, 95% CI: 0.17–0.18), followed by treated (0.10, 95% CI: 0.08–0.12) and untreated SHIP-TREND participants (0.08, 95% CI: 0.07–0.09). Evaluating the numbers of extracted teeth (Figure 1), the averaged estimate for untreated SHIP-TREND participants (4.85) overlapped with the smoothed curve for BARMER-MV patients during POST-TX phase.

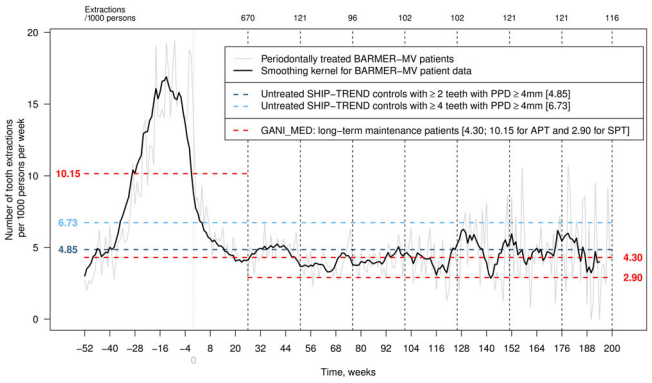

FIGURE 1 Numbers of tooth extraction per 1000 persons per week for periodontally treated BARMER-MV patients (light grey, solid line) are depicted. Time 0 (grey, dotted line) represents the billing date for periodontal therapy. For BARMER-MV patient data, a discrete symmetric normalized smoothing kernel was added (black). For periodontally untreated SHIP-TREND participants with either ≥2 (dark blue, 4.85) or ≥4 teeth with pocket probing depths (PPDs) ≥4 mm (light blue, 6.73), the average numbers of tooth extractions per 1000 persons and per week are shown. We additionally provided average numbers of tooth extractions per 1000 persons and per week for long-term maintenance patients from the GANI_MED cohort (red), separately for non-surgical periodontal treatment phase (10.15) and post-periodontal treatment phase (POST-TX; 2.90). APT, active periodontal treatment; SPT, supportive periodontal therapy

3.3 | Tooth loss in GANI_MED patients compared with severely affected SHIP-TREND groups

We now shift the focus to severely affected groups, that is, GANI_MED patients and periodontally untreated and treated SHIP-TREND participants with ≥4 affected teeth (Table 2, right part). YTL did not differ significantly between GANI_MED patients (0.34, 95% CI: 0.26–0.43) and untreated (0.26, 95% CI: 0.21–0.30) and treated SHIP-TREND participants (0.29, 95% CI: 0.21–0.37). However, incidence rates were significantly higher in GANI_MED patients than in untreated (IRR = 1.53, 95% CI: 1.22–1.91) or treated SHIP-TREND participants (IRR = 1.42, 95% CI: 1.05–1.93). Evaluating the numbers of extracted teeth (Figure 1), the averaged estimate for GANI_MED patients (4.30) was below the average estimate for untreated SHIP-TREND participants (6.73).

3.4 | Effects of periodontal treatment on tooth loss in SHIP-TREND

Periodontal treatment was associated with higher incidence rates in moderately to severely affected participants (IRR = 1.39, 95% CI: 1.04–1.85), but not in severely affected participants (1.17, 95% CI: 0.83–1.64, Table 3). Also, the average numbers of tooth extractions per 1000 persons per week in treated SHIP-TREND participants (6.94 and 7.93) were both higher than in untreated SHIP-TREND participants (4.85 and 6.73, Figure 1).

3.5 | Comparison of BARMER-MV with GANI_MED patients

Total YTL (0.35 vs. 0.34) and incidence rate estimates (0.18 vs. 0.15) did not differ markedly between BARMER_MV and GANI_MED patients. After differentiation according to NSPT and POST-TX phase, incidence rates during POST-TX were significantly lower in GANI_MED compared with BARMER-MV patients. For BARMER-MV patients, the graphical display of weekly numbers of tooth extractions provided more insight (Figure 1). Within the first 1.5 years,

TABLE 3 Associations of self-reported periodontal treatment (started between SHIP-TREND-0 and SHIP-TREND-1) with 7-year tooth loss using data from the Study of Health in Pomerania (SHIP-TREND). Participants with self-reported periodontal treatment within 5 years before SHIP-TREND-0 were excluded.

Number (%) of participants		Number of extracted teeth			
Without PT	With PT	Without PT	With PT	IRR (95% CI)	*p* Value
Participants with ≥2 teeth with PPD ≥4 mm (half-mouth protocol with four sites; *N* = 795)					
641 (80.7%)	154 (19.3%)	1.5 ± 2.7 0 (0; 2)	2.0 ± 3.2 1 (0; 2)	1.39 (1.04–1.85)	.026
Participants with ≥4 teeth with PPD ≥4 mm (half-mouth protocol with four sites; *N* = 478)					
362 (75.7%)	116 (24.3%)	1.9 ± 3.2 1 (0; 2)	2.2 ± 3.5 1 (0; 3)	1.17 (0.83–1.64)	.37

Note: For the number of extracted teeth, mean ± SD and median (Q25%; Q75%) are given. To determine IRRs for self-reported periodontal treatment (exposure) on the number of extracted teeth (outcome), negative binomial models adjusted for age (modelled as restricted cubic splines with three knots), sex, smoking, education and known or diagnosed diabetes were evaluated (with logarithmical follow-up time as offset variable).
Abbreviations: CI, confidence interval; IRR, incidence rate ratio; PPD, pocket probing depth; PT, periodontal treatment.

approximating the NSPT phase, the majority of teeth was extracted, equalling 670 teeth per 1000 persons. During POST-TX (after week 25), about 100 teeth per 1000 persons (range 96–121) were extracted during equally spaced time periods of 25 weeks each. In GANI_MED patients, the average numbers of tooth extractions were 10.15 for NSPT and 2.90 for POST-TX, the latter one being predominantly below the smoothed curve for BARMER-MV patients.

4 | DISCUSSION

In this study, three methods were applied to comprehensively analyse tooth loss data originating from three different studies, covering registry-based data, an observational study and a clinical cohort, all within the same catchment area. First, we showed notably higher tooth loss rates in periodontally treated BARMER-MV patients than in untreated SHIP-TREND participants with moderate to severe periodontitis (≥2 teeth with PPD ≥4 mm; half-mouth). Second, GANI_MED patients treated in a university setting had lower incidence rates during POST-TX than BARMER-MV patients treated in general practices. Third, during periodontal treatment, a higher number of teeth is extracted during NSPT: weekly numbers of tooth extractions were about twofold (BARMER-MV) to fourfold (GANI_MED) higher during NSPT compared with POST-TX.

We have considerably extended previous analyses of the registry data (Raedel et al., 2019) by two important points. First, we replaced the unspecific control group with clearly defined control groups with and without any periodontal treatment 5 years before baseline and during follow-up with two degrees of disease severity. Second, the existence of clinical periodontal data for the SHIP-based control groups allowed us to deduce periodontal disease severity in BARMER-MV patients. Transferring these data situation from treated SHIP-TREND-0 participants to BARMER-MV patients, we can assume that most of the BARMER-MV patients probably had moderate to severe periodontitis.

Tooth loss rates were notably higher in periodontally treated BARMER-MV patients than in untreated SHIP-TREND participants with moderate to severe periodontitis (≥2 teeth with PPD ≥4 mm; half-mouth). The second treatment group that came from SHIP-TREND supported the credibility of our findings, as in those higher tooth loss estimates were found compared with untreated SHIP-TREND controls. Importantly, just like BARMER-MV patients, SHIP-TREND participants were also treated by general dentists from Pomerania. However, for severely diseased subjects (≥4 affected teeth; half-mouth), results were inconclusive and did not support the assumption that periodontal treatment either conducted in the university (GANI_MED) or the general dental practice (SHIP-TREND) might be beneficial with regard to tooth loss in the short- or mid-term. Thus, periodontal treatment encompassing NSPT and POST-TX conducted in a general dental practice does probably not retain more teeth than no treatment in moderately to severely diseased periodontitis patients in the general population in North-eastern Germany.

One reason why periodontal treatment (as conducted until 2019 in the samples examined) did not result in a higher tooth retention rate may be that oral hygiene instruction or NSPT was insufficient because German patients had to pay for these sessions out of their own pocket and may have discontinued treatment because of money shortage. We have no information about whether BARMER patients were included in a structured maintenance programme or not, which is key to long-term success of periodontal treatment (Heasman et al., 2002).

After we had a closer look at the number of tooth extractions per week in BARMER-MV patients (see Figure 1), we divided the time period into two sections: the first 1.5 (approximating NSPT) and the last 3.5 years (approximating POST-TX). Extractions occurred more frequently during NSPT: weekly numbers of tooth extractions were about twofold higher during NSPT compared with POST-TX. During POST-TX, YTL (0.23) and incidence rates (0.17) were clearly reduced compared with NSPT. Comparing these BARMER-MV patient data with clinical cohort data from GANI_MED, we found that GANI_MED patients had lower incidence rates during POST-TX than BARMER-MV patients, despite the fact that periodontal treatment started earlier in GANI_MED patients (1993–2014) than in BARMER-MV patients (2011–2015). Additionally, average numbers of tooth extractions were consistently below smoothed curves of BARMER-MV patients, supporting the notion that periodontal treatment conducted in the clinic might, in the long term, retain more teeth compared with treatment conducted in the general dental practice. Furthermore, compared with recent data from four German university cohorts (Graetz et al., 2020), which reported values between 0.10 and 0.15 for maintenance, YTL was higher in BARMER-MV patients (0.17). This observation underpins that periodontal treatment works under stringent university premises but less well on a population level. The BARMER-MV data support the impression that under statutory insurance conditions no proper maintenance care is provided. The questionnaire of SHIP-Trend subjects adds a further sobering dimension: Only about 30% of the periodontally treated SHIP-Trend subjects reported to make use of a paid prophylaxis, whereas 70% of the periodontally treated subjects did not report prophylaxis sessions. In BARMER-MV patients, POST-TX treatment time was 3.5 years at maximum. Thus, we could only evaluate the short- to mid-term impact of periodontal treatment on tooth retention, but not any long-term impact or whether stabilization of periodontitis has occurred.

Until now, maintenance is not reimbursed by the German statutory health insurance. Thus, our results hint to the fact that in a real-world scenario periodontal treatment does not support the undisputed university view, that most patients benefit from periodontal treatment and that tooth loss is delayed. The reasons for these observations are open to discussion.

In July 2021, a new reimbursement scheme for periodontal treatment was introduced in Germany, which pays the dentist for motivation, instruction, scaling, monitoring, and 2 years of maintenance (Gemeinsamer Bundesausschuss, 2021). Thus, a part of our criticism may fall short, and it will be interesting to see in the future if periodontal treatments are conducted more often and to a higher standard than those shown in this study.

The following strengths need to be emphasized. First, BARMER-MV patients, SHIP-TREND groups and GANI_MED patients were drawn from the same source population (the German Federal State of

Mecklenburg-Vorpommern). Thus, BARMER-MV patients, SHIP-TREND participants and GANI_MED patients shared the same demographic and socio-economic environment, and may have a similar distribution of behavioural risk factors or comorbidities. Also, BARMER-MV patients and SHIP-TREND participants were probably treated by local family dentists. Second, to methodologically address differences in tooth loss rates, we estimated two different measures, that is, YTL and incidence rates. However, both estimates have their advantages and drawbacks. While YTL estimates consider the total number of extracted teeth per person, they are highly impacted by short observation times (especially <1 year), resulting in high YTL estimates and increased right-skewness of the distribution, thereby aggravating meaningful interpretation of the mean, as mostly done in dental articles. Also, observation times until extraction are not considered. The incidence rate is defined as the quotient of the number of subjects with at least one extraction event divided by totalled observation times (in person-years). However, it requires that observation times until first extraction events are defined. As this information was not available for SHIP-TREND and GANI_MED, event times were approximated. Furthermore, only first extraction events per subject are considered; however, short observation times do not negatively affect its calculation, as person-times are totalled. Fourthly, BARMER-MV and GANI_MED patients had shorter follow-up times compared with SHIP-TREND groups. Lastly, we have used the curve for the number of extractions per week to differentiate between NSPT and POST-TX in BARMER-MV patients. While it might be discussed whether the chosen cut-off of 1.5 years reflects the transition from NSPT to POST-TX in all patients, it allowed a more detailed comparison of tooth loss estimates between BARMER-MV patients and comparison groups.

The following limitations deserve consideration. Untreated SHIP-TREND-0 controls were selected such that sex- and age-specific distributions of tooth counts were comparable to those from BARMER-MV patients. While untreated SHIP-TREND-0 controls had a mean PPD of 2.73 and 2.96 mm, respectively, treated SHIP-TREND-0 controls had a mean PPD of 2.97 and 3.12 mm, respectively. It can be assumed that BARMER-MV patients had mean PPDs comparable to those reported for treated SHIP-TREND-0 controls, but lower than those reported for GANI_MED patients. However, a mean PPD of ≤3.00 mm does not equate severe periodontitis (Kocher et al., 2018). Second, only the number of periodontally treated teeth was available for BARMER-MV patients, but not the exact number of teeth. Since clinical data were not available for BARMER-MV patients, we had to refer to clinical data from SHIP for our argumentation. Furthermore, we had no information about risk factors and comorbidities (e.g., education, income smoking, diabetes), which would have been important for an adjustment of the analyses. Moreover, we did not know how many patients obtained a *lege artis* periodontal therapy fitting the accepted standards. We do not consider this as a significant shortcoming, since these routine data provide an appropriate reflection of how the population was actually treated. Routine data such as the BARMER-MV data set originating from claims data do not encompass the required information to appropriately assess the treatment quality standard. This does not only apply to periodontal treatment and is well known from the growing number of analyses in health services research. Routine data reflect the outcome of treatments as executed under practice conditions. Depending on the perspective, this weakness can also be seen as a strength. General dentists have to merge guidelines and recommendations with patient- and practice-specific conditions. The BARMER-MV data refer to the outcome of billed periodontal treatment in clinical reality in Germany, not under controlled conditions. We selected controls from SHIP-TREND-0 because examination times (2008–2012) best fitted treatment periods of BARMER-MV patients (2011–2015), thereby minimizing cohort effects (Schutzhold et al., 2013). To counter-check our results, we analysed the effects of self-reported periodontal treatment on 7-year tooth loss (SHIP-TREND-0 as baseline, Table 3). Incidence rates for tooth loss in periodontally treated participants were 1.39-fold (95% CI: 1.04–1.85) and 1.17-fold (95% CI: 0.83–1.64) higher compared with non-treated participants. These results concurred with results from comparisons of BARMER-MV patients with untreated SHIP-TREND controls. Fourthly, SHIP-TREND controls had longer follow-up times compared with BARMER-MV patients. However, analyses of YTL and incidence rates adequately accounted for different follow-up times. Fifthly, the number of periodontally affected teeth in SHIP controls was based on data from a half-mouth assessment protocol, thereby underestimating the extent and severity. Sixthly, we did not know at what time point teeth were extracted in SHIP-TREND participants. Thus, we assumed that extraction occurred halfway between SHIP-TREND-0 and SHIP-TREND-1. This might have affected incidence rate estimates to an unknown direction and extent. Lastly, we were only partly able to support study conclusions by inferential statistical testing, since it was not possible to merge the registry data with any of the other data sets.

5 | CONCLUSION

Despite the limitations, the results suggest that periodontal treatment of patients with moderate to severe periodontitis does not lead to an improved tooth retention rate during the short- or mid-term compared with untreated subjects from a population-based perspective. Thus, it will be of utmost interest to conduct appropriately designed future studies to evaluate the changes in the benefit of tooth retention after the implementation of the new reimbursement scheme in Germany.

AUTHOR CONTRIBUTIONS

Thomas Kocher, Birte Holtfreter, Christian Graetz, Lukasz Jablonowski, Michael Raedel and Michael H. Walter contributed substantially to the conception or design of the work; Thomas Kocher, Henry Völzke, Hans J. Grabe, Michael Raedel and Michael H. Walter contributed to the acquisition of data. Thomas Kocher, Birte Holtfreter, Heinz-Werner Priess, Lukasz Jablonowski, Christian Graetz, Michael Raedel and Michael H. Walter contributed to the analysis and interpretation of data. Thomas Kocher, Birte Holtfreter, Michael Raedel and Michael H. Walter drafted the work; all authors revised the manuscript critically for important intellectual content. All authors finally approved the version to be published. All coauthors

agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CONFLICT OF INTEREST

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ETHICS STATEMENT

The nationwide massive data analysis on the treatment outcome was approved by the responsible local Ethics Committee at Technische Universität Dresden (EK 288072015). For this type of study, no patient consent statement is required. For SHIP-TREND and GANI_MED, study protocols were approved by the local Ethics Committee at Greifswald University (SHIP-TREND-0: BB 39/08a issued on 3 September 2009; SHIP-TREND-1: BB 174/15, issued 12 December 2015, GANI_MED: BB 91/10 issued on 28 July 2010) and written informed consent was obtained from each participant.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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