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Effect of Discontinuation of Supportive Periodontal Therapy on Periodontal Status—A Retrospective Study

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ABSTRACT

Aim: To assess the impact of active (APT) and supportive periodontal therapy (SPT) on the change in probing depth (PD) and annual tooth loss in partially and fully compliant and drop-out patients.

Material and Methods: Data of 280 periodontally treated partially and fully compliant (regular supportive visits, SPT duration 5.5 ± 4.5 years) and 55 drop-out patients (SPT and drop-out duration 8.3 ± 3.8 years, only drop-out duration 5.3 ± 3.7 years) were recorded. PD data and the number of teeth present at the start of APT (T1) and at the start of SPT (T2) were taken from the patient files and evaluated at the time of the final examination (T3).

Results: Annual tooth loss during SPT was significantly higher ($p < 0.001$) in drop-out patients than in partially and fully compliant patients (0.31 ± 0.50 vs. 0.19 ± 0.55, respectively). In partially and fully compliant and drop-out patients, the mean PD (all available site data) decreased significantly between T1 (3.61 ± 0.82 vs. 3.70 ± 0.73 mm) and T2 (2.68 ± 0.40 vs. 2.76 ± 0.42 mm), while the values increased again slightly up to T3 (2.74 ± 0.41 vs. 2.99 ± 0.75 mm).

Conclusions: In partially and fully compliant patients, SPT had a positive impact on PD stability and medium-term tooth preservation. In contrary to expectations, drop-out patients, PD did not return to baseline values, although PD stability was not achieved.

1 | Introduction

The goal of periodontal therapy is to improve the oral quality of life, to stabilize periodontal structures and to preserve the dentition in the long term (Sanz et al. 2020). During supportive periodontal therapy (SPT), the annual rate of tooth loss in compliant patients ranged between 0.1 and 0.2 or averaged 0.12 in long-term retrospective studies (Carvalho et al. 2021; Helal et al. 2019). In prospective cohorts, 9.6% of compliant patients lost more than one tooth during 5–20 years of SPT (Leow et al. 2021). In retrospective cohorts of compliant patients, the mean probing depth (PD) ranged between 0.8 and 1.4 mm after active periodontal therapy (APT) (De Wet, Slot, and Van der Weijden 2018; Matuliene et al. 2008). In contrast to the impact of periodontal treatment on PD reduction and tooth loss, quality of life has become a focus of the periodontal research community only in the last few decades (Wong, Yap, and Allen 2021).

The survival rate of teeth depends on risk factors such as age, smoking, general health status, social status and compliance (Helal et al. 2019). Probably, appointment compliance is one of the most important factors for long-term tooth retention

(Chambrone et al. 2010; Lee et al. 2015; Ramseier et al. 2019; Ravida et al. 2021), although the definition of good, erratic/irregular and non-compliance varied considerably in the literature (Amerio et al. 2020; Lee et al. 2015). Patients with erratic compliance showed significantly increased odds ratios of tooth loss compared to patients with good compliance (OR 1.51, 95% confidence interval [CI]: 1.06–2.16) and, vice versa, patients with good compliance showed significantly lower risk ratio of tooth loss (RR = 0.56, 95% CI: 0.38–0.82) compared to those with erratic compliance (Helal et al. 2019; Lee et al. 2015). A small retrospective study reported that untreated patients lost 0.46 ± 0.60 teeth/year, drop-outs 0.41 ± 0.72 teeth/year and compliant patients 0.16 ± 0.30 teeth/year (Kocher et al. 2000).

Insufficient information is available on the periodontal status of patients who discontinue periodontal therapy, although their proportion is not negligible. In 17 studies with a follow-up period of up to 20 years, the number of drop-out patients ranged from 1.69% to 64.4% (median: 29%) (Amerio et al. 2020). The question therefore arises as to whether dropouts benefit from their periodontal treatment or whether dropping out completely negates the periodontal treatment efforts. Based on the current literature, the European Federation of Periodontology (EFP)/American Academy of Periodontology (AAP) 2020 S3 treatment guideline concludes 'untreated or inadequately treated periodontitis leads to the loss of tooth-supporting tissues and teeth' (Sanz et al. 2020). The hypothesis of this retrospective study was that discontinuation of SPT results in a rebound of PD, in increased tooth loss and in reduced quality of life.

2 | Material and Methods

2.1 | Study Design

This study is part of the 'Greifswald Approach to Individualized MEDicine' (GANI_MED) project (Grabe et al. 2014). The study protocol was approved by the local ethics committee of the Medical Faculty of University Greifswald (application no. GANI_MED: BB 91/10 dated on 28 July 2010). All enrolled participants gave their written informed consent. Guidelines of the 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) were followed.

2.2 | Patient Cohort Design

The following inclusion criteria were defined: patients with chronic periodontitis according to the 1999 Classification of Periodontitis (Armitage 1999) listed in the patient registry of the Unit of Periodontology, University Medicine Greifswald, Germany; the presence of at least one site with PD >4 mm at the initial examination; and completion of APT.

2.3 | Treatment Modalities

APT included oral hygiene instruction, prophylaxis, non-surgical periodontal therapy and additional periodontal surgery in sites with residual PD ≥6 mm. ATP was completed approximately

1 year after the initial examination. The therapeutic focus was on non-surgical periodontal therapy; an access flap surgery was performed when indicated. SPT was recommended at intervals of 3–6 months and included oral hygiene re-instruction and re-motivation, annual examination of PD at six sites per tooth, subgingival debridement of residual pockets ≥5 mm, professional tooth cleaning and fluoridation (Graetz et al. 2020).

2.4 | Recruitment

This study was performed between 2011 and 2014. According to the patient register, 3040 patients were treated in the Unit of Periodontology between 1995 and 2010. Out of these, 1268 were partially and fully compliant and 1772 were dropouts (Figure 1). Of these, 939 partially and fully compliant and 548 drop-out patients were randomly selected and contacted. The patients were informed about the study in writing and asked to participate voluntarily. In the end (after excluding those who refused to participate, did not make an appointment, had cancelled an appointment or did not show up), 367 (response 39.1%) partially and fully compliant and 112 drop-out patients (response 20.4%) participated. After exclusion of patients with missing somatometric, periodontal or covariate data, the final data set for analyses of (i) longitudinal tooth loss data included 280 partially and fully compliant and 56 drop-out patients and (ii) periodontal data included 269 partially and fully compliant and 55 drop-out patients.

2.5 | Patient Status

Patients were classified as 'fully compliant' if they had attended SPT on average at least once a year, and as partially compliant if they attended on average regularly but less often than once a year. As demographic variables and periodontal outcomes were not different between the two groups, we pooled them (Tables S1–S3). Patients who dropped out during SPT and did not attend further SPT were classified as 'drop-out patients'.

2.6 | Periodontal and Dental Status

At the final examination (T3), the number of teeth was counted, excluding third molars. In addition, full-mouth PDs were measured at six sites per tooth using a manual periodontal probe (PCP15, Hu-Friedy, Chicago, IL, USA) and rounded mathematically to the nearest millimetre. Bleeding on probing (BOP) and plaque (full-mouth on a maximum of 28 teeth; six surfaces) were reported as percentages of affected sites. Mean PD (in mm) and the percentages of sites with PD ≥4 (%PD4+) or ≥6 mm (%PD6+) were calculated.

The three GANI_MED examiners carrying out T3 examinations were trained and calibrated. For PD, the pairwise inter-rater ICCs ranged between 0.78 (95% CI: 0.73–0.82) and 0.85 (95% CI: 0.82–0.88). The intra-rater ICCs ranged between 0.76 (95% CI: 0.71–0.80) and 0.87 (95% CI: 0.84–0.90).

PD levels and number of teeth, excluding third molars, at start of APT (T1) and SPT (T2) were retrieved from patient records,
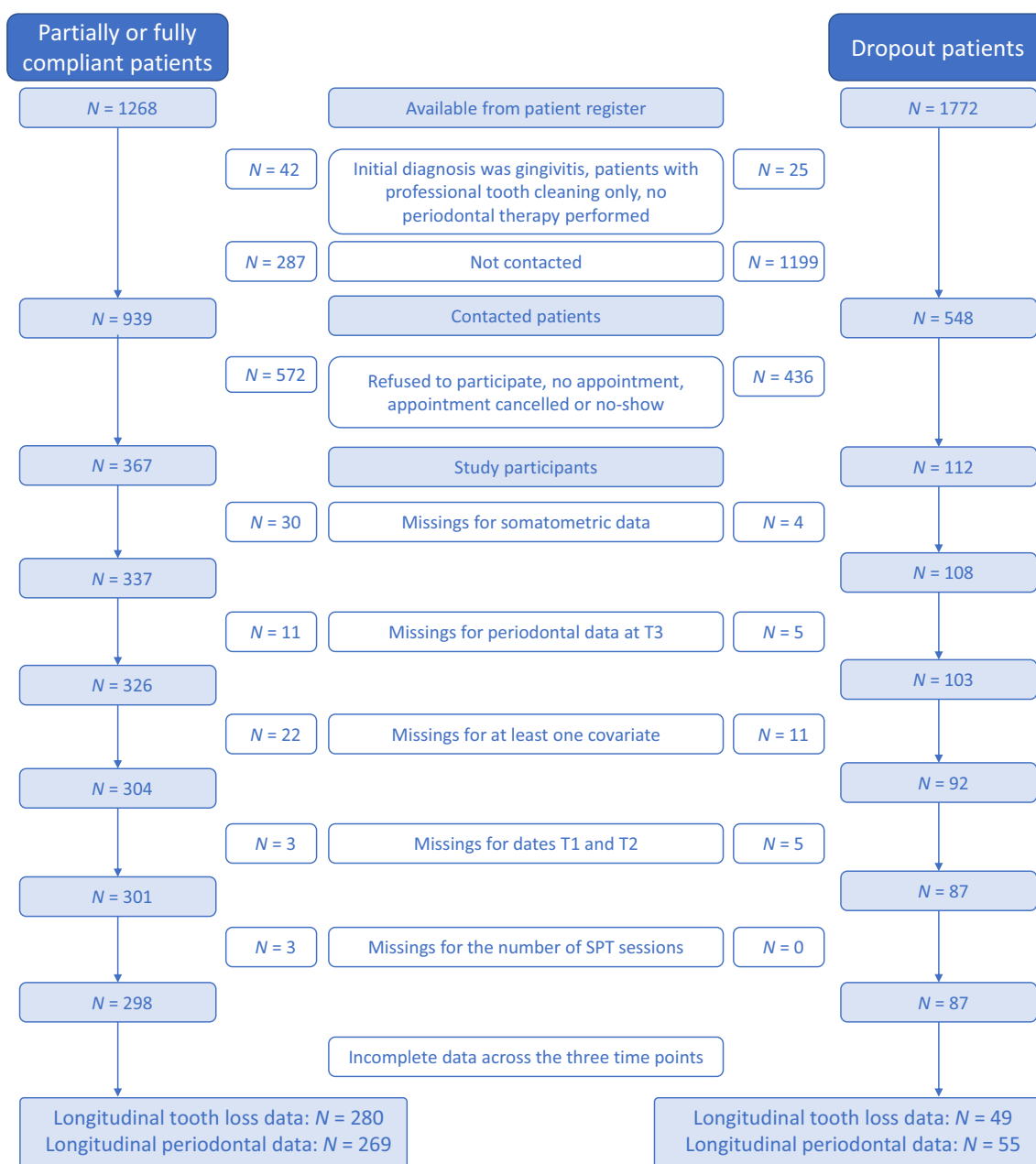
FIGURE 1 | Flow chart of patient recruitment and data compilation.

including the number of sessions during SPT, the duration of APT (time between T1 and T2) and SPT (time between T2 and T3) and maximum periodontal therapy across all teeth during APT and/or SPT (yes/no; reported per tooth; non-surgical vs. surgical therapy). T3 was the final SPT visit for compliant patients. For drop-out patients, the time between last SPT visit and T3 was noted as the drop-out duration. Routine charting was performed by different dentists at T1 and T2; there are no reliability data.

2.7 | Outcomes

We evaluated mean PD, %PD4–5 and %PD6+, the percentage of sites with BOP, plaque and the number of teeth present at T1, T2 and T3. In addition, annual tooth loss rates due to all causes during APT and SPT were analysed.

2.8 | Statistical Analysis

For continuous variables, means ± standard deviations and medians (25% and 75% quantiles) were calculated; distributional differences between both patient groups were examined using Mann–Whitney U tests. For categorical variables, frequency distributions were reported as numbers (percentages), and group differences were analysed using Chi-squared tests. Changes in periodontal variables between T1, T2 and T3 were analysed by (i) including all available sites or (ii) excluding sites from incidentally extracted teeth and sites with incomplete PD data. Wilcoxon rank sum tests for paired data were used to evaluate distributional changes in periodontal parameters and the number of teeth. Using negative binomial regression models, associations of treatment group (reference group: partially and fully compliant patients; indicator group: drop-out patients) with the

number of teeth extracted during SPT were estimated, adjusting for age, sex, school education, smoking status and diabetes. Incidence rate ratios (IRRs) with 95% CI and *p*-values were reported. The changes in PD values (maximum PD per tooth) and extraction status from T1 to T3 were visualized using Sankey graphs.

Statistical significance was declared for *p*-values <0.05. Statistical analyses were conducted using Stata 17.0 (StataCorp 2021).

3 | Results

3.1 | Patient Characteristics

At T1, the mean age was 56.5 years in partially and fully compliant patients ($N = 280$) and 56.8 years in drop-out patients ($N = 56$) (Table 1). Socio-economic and risk factor profile did not differ significantly between the two groups. APT duration was 4.1 months longer in partially and fully compliant patients than in drop-out patients. Drop-out patients had not had SPT for an average of 5.3 ± 3.7 years since their last SPT visit, and 38.3% discontinued SPT in the first year. In contrast, the type of periodontal therapy (non-surgical or surgical periodontal therapy) did not differ significantly between the two groups. In both groups, about 30% of patients underwent flap surgery.

3.2 | Oral Hygiene and Patient-Reported Oral Health Measures

At T3, toothbrushing frequency and regular interdental hygiene did not differ significantly between partially and fully compliant and drop-out patients (Table 1). Partially and fully compliant patients were more likely to use a powered toothbrush (67.1% vs. 53.5%). Forty percent of partially and fully compliant patients rated the health of their teeth as very good or good, compared to 32.1% of drop-out patients. Among partially and fully compliant patients, 70% were 'very satisfied' or 'satisfied' with the appearance of their teeth, compared to 60.7% of drop-out patients.

3.3 | Change in Periodontal Parameters and Number of Teeth

At T3, partially and fully compliant patients had less plaque ($42.9\% \pm 23.9$) and BOP ($45.4\% \pm 13.6$) compared to drop-out patients ($62.3\% \pm 26.8$ and $55.4\% \pm 17.7$, respectively) (Table 2). At T1 and T2, the mean PD and percentages of affected sites did not differ between partially and fully compliant and drop-out patients (Table 2, Figure 2). In both groups, mean PD and %PD6+ decreased significantly between T1 and T2, approximately by 0.9 mm, 26%, and 11%, respectively. Between the T2 and T3, the mean PD increased by 0.06 mm in partially and fully compliant patients and by 0.23 mm in drop-out patients. In parallel, the mean PD and %PD6+ increased in both groups, with higher increases in drop-out patients. At T3, the mean PD, %PD4–5 and %PD6+ differed significantly between both groups ($\Delta = 0.25$ mm, $\Delta = 6.4\%$ and $\Delta = 3.8\%$, respectively, Figure 2A–C). From T1 to T2 to T3, the number of teeth decreased significantly in both groups (Table 2).

At T3, partially and fully compliant patients had an average of 1.1 more teeth than drop-out patients ($p = 0.1309$; Figure 2D).

To illustrate the influence of incidentally extracted teeth on PD values over different time points, we presented PD values (A) including all available site data and (B) excluding extracted teeth and sites with incomplete PD data (Table 2). We found that exclusion of extracted teeth and sites with incomplete PD data did not contribute significantly to the change of the periodontal status from T1 to T2 or from T2 to T3 in both groups.

Using the tooth level data (evaluation of maximum PD per tooth), we visualized the changes in maximum PD values and extraction status from T1 to T3 using Sankey plots. The transition pattern between T1 and T2 was similar in both groups of patients. Approximately 70% of the teeth with PD4–5 mm migrated to the PD1–3 mm category and approximately 35% of the teeth with PD6+ mm migrated to the PD1–3 mm and PD4–5 mm categories. The extracted teeth were mainly from the PD6+ mm category. However, the pattern of migration from T2 to T3 differed between groups. In partially and fully compliant patients, approximately 30% and in the dropouts approximately 40% of the PD1–3 mm teeth migrated into the PD4–5 mm category. In the partially and fully compliant patients, 15% of PD4–5 mm teeth and in the dropouts approximately 25% migrated into the PD6+ mm category. In both groups, the extracted teeth at T3 came equally from all three probing depth categories.

To investigate whether the extraction patterns differed between the two groups, we plotted the distributions of the maximum PD for the teeth extracted during APT and SPT in partially and fully compliant and drop-out patients (Figure 4). The PD distribution of the extracted teeth did not differ between the two groups in APT and SPT. At T1 (Figure 4A,C), most extracted teeth (90.4% and 87.7%, respectively) had a PD ≥5 mm, whereas at T2 (Figure 4B,D) the majority of teeth had a PD of only 3 or 4 mm (55.9% and 54.2%, respectively) and only very few teeth had a PD ≥6 mm (24.4% and 24.9%, respectively). Overall, most of the extracted teeth at T2 did not have deep residual PDs.

3.4 | Annual Tooth Loss During APT and SPT

Annual tooth loss during APT was similar (mean 0.75 ± 2.09 and 0.98 ± 1.74) in partially and fully compliant and drop-out patients (Table 3). In contrast, the mean number of teeth extracted during SPT was nearly 3 times higher in drop-out patients (2.00 ± 2.78) than in partially and fully compliant patients (0.74 ± 1.53). Consequently, the annual tooth loss during SPT was significantly higher in drop-out patients (0.31 ± 0.50) than in partially and fully compliant patients (0.19 ± 0.55). The adjusted incidence rate for tooth loss during SPT was twice as high in drop-out patients (IRR = 2.20; 95% CI: 1.31–3.70) as in partially and fully compliant patients.

4 | Discussion

This study investigated the effect of discontinuation of periodontal therapy on periodontal status. Mean PD, %PD4–5 and %PD6+ decreased notably during APT in both partially and

TABLE 1 | Patient characteristics at the time of T3 examination.

	Compliant patients (N = 280)	Drop-out patients (N = 56)	p-value
GANI_MED examination year			
2011	19 (6.8%)	0 (0%)	
2012	176 (62.9%)	6 (10.7%)	
2013	55 (19.6%)	46 (82.1%)	
2014	30 (10.7%)	4 (7.1%)	<0.0001
Age, years	56.5 ± 10.4	56.8 ± 10.8	0.856
	56.3 (48.8; 64.5)	54.0 (49.1; 64.4)	
Male sex	130 (46.4%)	25 (44.6%)	0.807
Education			
<10 years	31 (11.1%)	8 (14.3%)	
10 years	82 (29.3%)	20 (35.7%)	
>10 years	167 (59.6%)	28 (50.0%)	0.407
Smoking status			
Never smoker	129 (46.1%)	22 (39.3%)	
Former smoker	100 (35.7%)	22 (39.3%)	
Current smoker	51 (18.2%)	12 (21.4%)	0.638
Family status			
Single	44 (15.7%)	14 (25.0%)	
Married/cohabiting	207 (73.9%)	36 (64.3%)	
Divorced/non-cohabiting	20 (7.1%)	3 (5.4%)	
Widowed	9 (3.2%)	3 (5.4%)	0.290
Waist circumference, cm	93.9 ± 14.6	96.1 ± 12.8	0.2373
	93 (83; 103)	95.5 (86.0; 103.5)	
Body mass index, kg/m^2 (N = 275/55)	27.3 ± 4.9	27.9 ± 4.5	0.2155
	26.3 (23.9; 29.9)	27.3 (24.8; 30.9)	
Diabetes mellitus, yes	22 (7.9%)	10 (17.9%)	0.020
Hyperlipidaemia, yes	66 (23.6%)	9 (16.1%)	0.219
Toothbrushing frequency			
≤1 daily	17 (6.1%)	1 (1.8%)	
Twice daily	243 (86.8%)	54 (96.4%)	
≥3 times daily	20 (7.1%)	1 (1.8%)	0.120
Type of toothbrush			
Manual toothbrush	92 (32.9%)	26 (46.4%)	
Electric toothbrush	126 (45.0%)	19 (33.9%)	
Both	62 (22.1%)	11 (19.6%)	0.142
Daily use of interdental cleaning aids, yes	170 (60.7%)	28 (50.0%)	0.137

(Continues)

TABLE 1 | (Continued)

	Compliant patients ($N=280$)	Drop-out patients ($N=56$)	p-value
Health condition of the teeth			
Very good or good	112 (40.0%)	18 (32.1%)	
Satisfactory	95 (33.9%)	19 (33.9%)	
Bad or very bad	73 (26.1%)	19 (33.9%)	0.386
Appearance of the teeth			
Very satisfied or satisfied	196 (70.0%)	34 (60.7%)	
Less satisfied or unsatisfied	84 (30.0%)	22 (39.3%)	0.172
Diagnosis			
Aggressive periodontitis	34 (12.1%)	10 (17.9%)	
Chronic periodontitis	246 (87.9%)	46 (82.1%)	0.247
Number of visits during SPT	11.6 ± 10.4	5.4 ± 6.8	0.0001
	8 (3; 17)	2 (1; 8)	
APT duration (T1–T2), months ($N=278/47$)	15.2 ± 9.3	11.1 ± 5.9	0.0007
	12.7 (9.0; 18.8)	10.3 (7.3; 12.0)	
Time between T2 and T3[a], years ($N=278/47$)	5.5 ± 4.5	8.3 ± 3.8	0.0001
	4.3 (1.6; 9.4)	8.6 (5.6; 11.6)	
Drop-out duration, years ($N=47$)	—	5.3 ± 3.7	—
		5.2 (1.9; 8.5)	
Periodontal therapy during APT and/or SPT			
Non-surgical therapy	193 (68.9%)	40 (71.4%)	
Surgical therapy	84 (30.0%)	16 (28.6%)	
Missing	3 (1.1%)	0 (0%)	0.714

Note: p-values were retrieved from Mann–Whitney *U* tests or Chi-squared tests. Data are presented as mean ± standard deviation and median (25%, 75% quantiles) or number (percentage). Diabetes mellitus and hyperlipidemia were defined as a statement by the patient confirmed by the physician.
Abbreviations: GANI_MED, Greifswald Approach to Individualized MEDicine; SPT, supportive periodontal treatment.
[a]Equals SPT duration for compliant patients.

fully compliant and compliant patients. In partially and fully compliant patients, SPT had a positive effect on PD stability and medium-term tooth preservation, whereas in drop-out patients the lack of SPT led to moderate recurrence of PD. Despite this recurrence, the T3 periodontal status of drop-out patients still showed a significant improvement compared to the T0 level, while the annual rate of tooth loss during T2–T3 was about one-third higher in non-compliant patients compared with partially and fully compliant patients (0.31 ± 0.50 vs. 0.19 ± 0.55).

Although the definition of a partially and fully compliant, erratic, non-compliant or drop-out SPT patient is highly heterogeneous in the literature, the percentage of 41.7% partially and fully compliant patients in our cohort is consistent with the reported percentages of compliance in a systematic review (3.3%–86.8%) (Amerio et al. 2020). The observed annual tooth loss rate of 0.19 teeth per year in partially and fully compliant patients is within the reported distribution of 0.05–0.26 teeth per year (Carvalho et al. 2021; Echeverria, Echeverria, and Caffesse 2019). For drop-out patients, the annual tooth loss rate of 0.31 found in our study is also consistent with reported annual rates of 0.22–0.41

(Becker, Becker, and Berg 1984; Goh et al. 2017; Kim et al. 2014; Leung et al. 2006; Ng et al. 2011).

Since we do not know the actual reason for extraction, we must speculate on the reasons why dropouts lost almost twice as many teeth during SPT as partially and fully compliant patients. Since the extraction patterns during T2–T3 (Figure 4) and the mean PD, PD4–5 and %PD6+ reductions did not differ between the two groups (Figure 2), we concluded that the dropouts did retain as many compromised teeth at T2 as the partially and fully compliant patients. The Sankey plots (Figure 3) showed that a similar proportion of compromised teeth were extracted in both groups between T2 and T3 in both groups, and histograms of the maximum probing depth at T2 (Figure 4) showed that approximately 25% of extracted teeth in both groups had PD6+. As the recurrence of periodontal pockets is much higher in dropouts, we do not know whether the extracted teeth in this group were extracted because they were compromised or for other reasons. In the periodontal literature, SPT is mainly discussed in terms of stabilizing the periodontal situation and preserving periodontally compromised teeth (Kim et al. 2014); however, our observation

TABLE 2 | Comparison of periodontal variables (for probing depth variables: including and excluding incidentally extracted teeth and incomplete probing depth data) and number of teeth between the start of active periodontal therapy (APT) (T1), the start of supportive periodontal therapy (SPT) (T2) and the final examination (T3) for partially and fully compliant and dropout patients.

	T1	T2	T3	T1	T2	T3	p-value[a]
	Compliant patients (N = 258)			Drop-out patients (N = 55)			
Percentage of sites with plaque, %	—	—	42.9 ± 23.9	—	—	62.3 ± 26.8	0.0001
			40.5 (24.3; 58.3)			56.3 (41.0; 89.4)	
	Partially and fully compliant patients (N = 256)			Dropout patients (N = 55)			
Percentage of sites with BOP, %	—	—	45.4 ± 13.6	—	—	55.4 ± 17.7	0.0001
			42.9 (33.3; 53.4)			51.0 (39.6; 69.4)	
Including all available site data							
	Partially and fully compliant patients (N = 269)			Drop-out patients (N = 55)			
Mean PD, mm	3.61 ± 0.82	2.68 ± 0.40	2.74 ± 0.41	3.70 ± 0.73	2.76 ± 0.42	2.99 ± 0.75	0.0540
	3.49 (3.02; 4.02)	2.65 (2.39; 2.89)	2.69 (2.45; 2.92)*,**	3.53 (3.13; 4.12)	2.72 (2.43; 3.10)	2.76 (2.51; 3.31)*,**	
Percentage of sites with PD ≥4 mm, %	39.0 ± 19.8	12.3 ± 11.7	17.9 ± 13.0	40.5 ± 18.8	12.4 ± 11.7	24.3 ± 18.5	0.0276
	37.8 (23.5; 53.3)	8.7 (4.2; 16.7)	15.1 (8.3; 24.3)*,**	39.8 (24.0; 56.3)	10.5 (3.8; 17.9)	21.0 (9.4; 34.3)*,**	
Percentage of sites with PD ≥6 mm, %	13.0 ± 14.0	2.0 ± 3.1	2.6 ± 3.9	13.0 ± 13.7	2.3 ± 3.4	6.5 ± 11.0	0.0038
	8.0 (2.8; 18.7)	0.6 (0; 2.8)	1.1 (0; 3.0)*,**	7.7 (4.2; 16.7)	1.3 (0; 3.0)	2.5 (0.6; 7.2)*,**	
Excluding extracted teeth and sites with incomplete probing depth data							
	Compliant patients (N = 269)			Drop-out patients (N = 55)			
Mean PD, mm	3.53 ± 0.78	2.65 ± 0.39	2.71 ± 0.42	3.57 ± 0.68	2.72 ± 0.39	2.96 ± 0.75	0.0435
	3.42 (2.98; 3.92)	2.62 (2.39; 2.87)	2.68 (2.44; 2.89)*	3.47 (3.02; 3.98)	2.67 (2.43; 3.00)	2.74 (2.48; 3.22)*,**	
Percentage of sites with PD ≥4 mm, %	37.4 ± 19.7	11.7 ± 11.5	17.0 ± 13.0	37.8 ± 19.0	10.9 ± 11.3	23.5 ± 18.3	0.0160
	36.5 (21.0; 51.7)	8.3 (3.8; 15.4)	14.1 (7.9; 22.5)*,**	35.2 (18.8; 52.4)	9.0 (2.8; 14.4)	20.4 (9.0; 31.2)*,**	
Percentage of sites with PD ≥6 mm, %	11.7 ± 13.2	1.7 ± 2.8	2.5 ± 3.9	10.8 ± 13.0	2.0 ± 3.1	6.3 ± 11.0	0.0010
	6.5 (2.2; 17.4)	0.6 (0; 2.5)	0.9 (0; 3.0)*,**	5.8 (2.9; 15.1)	0.8 (0; 2.9)	2.5 (0.6; 6.1)*,**	
	Compliant patients (N = 280)			Drop-out patients (N = 49)			
Number of teeth (max. 28)	23.5 ± 4.2	22.8 ± 4.9	22.0 ± 5.2	23.6 ± 4.0	22.9 ± 4.2	21.0 ± 5.4	0.1309
	24 (21; 27)	24 (20; 27)	23 (19; 26)*,**	24 (22; 27)	24 (21; 26)	22 (19; 24)*,**	

Note: Data are presented as mean ± standard deviation and median (25%; 75% quantiles).

Abbreviations: APT, active periodontal therapy; BOP, bleeding on probing; PD, probing depth; SPT, supportive periodontal therapy.

[a]p-values from Mann–Whitney U tests comparing compliant with dropout patients at T3.

*p < 00.05 comparing T3 versus T1 using t-tests or Wilcoxon rank-sum tests for paired data, as appropriate.

**p < 0.05 comparing T3 versus T2 using t-tests or Wilcoxon rank-sum tests for paired data, as appropriate.
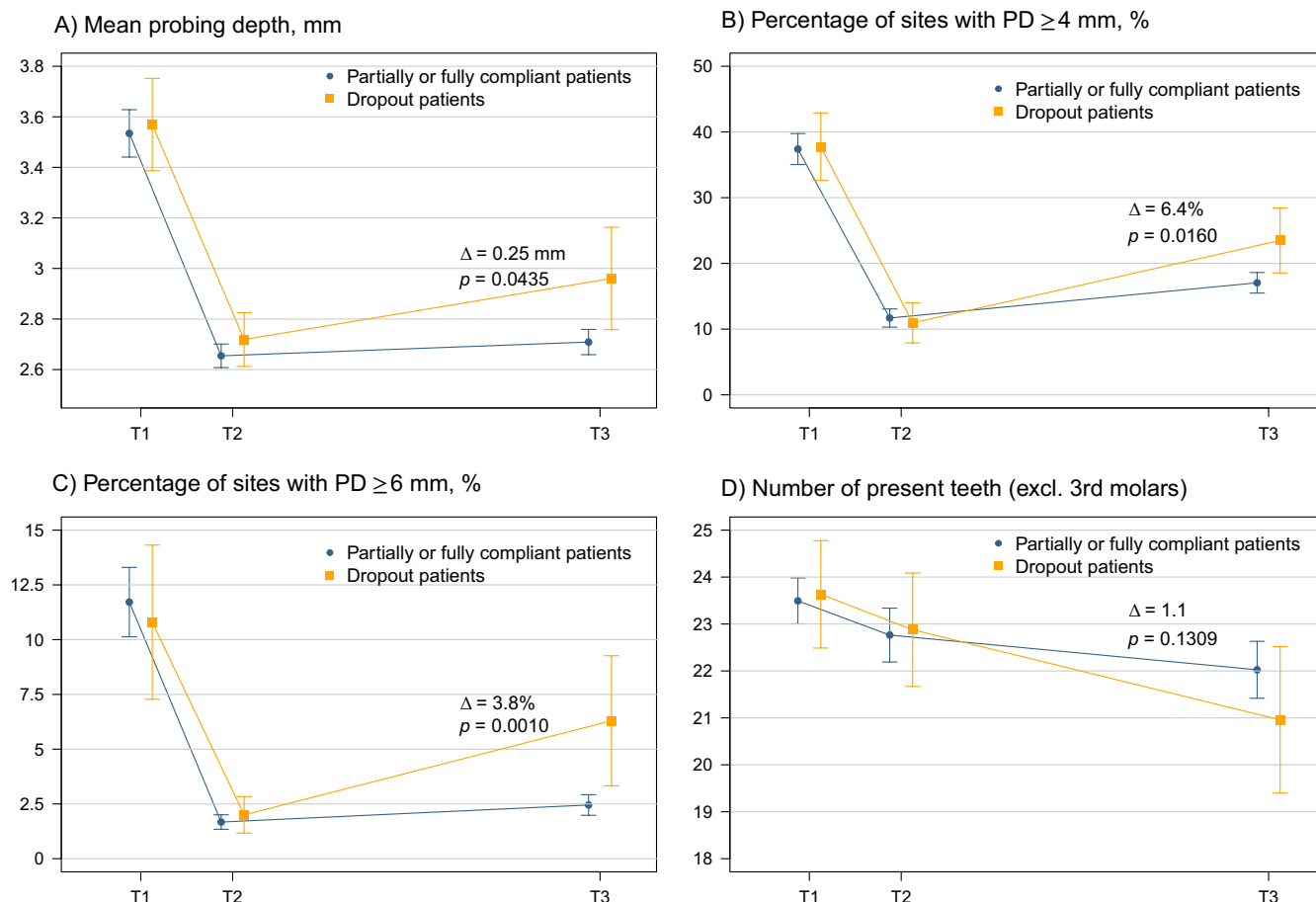
FIGURE 2 | Time course of means and respective 95% confidence intervals of (A) mean probing depth, (B) percentage of sites with probing depths ≥4 mm, (C) percentage of sites with probing depths ≥6 mm and (D) number of present teeth (excluding third molars) in partially and fully compliant (dark blue) and drop-out patients (orange). Differences in means (Δ) and p-values from Mann–Whitney U tests are shown.

that compromised teeth (residual PD6+ mm at T2) were not more likely to survive in partially and fully compliant patients than in drop-out patients does not support this explanation. The most likely explanation is that the benefits of SPT contributed to a much lower rate of tooth loss in partially and fully compliant patients compared with non-compliant patients, because a strict SPT regimen includes regular fluoridation and prevents the progression of caries and its sequelae (Axelsson and Lindhe 1981). In line with our observation, a systematic review found that only between 0.45% and 14.4% of teeth were extracted for periodontal reasons during SPT in compliant patients (Carvalho et al. 2021). In a Korean study, 0.4% of teeth with a good prognosis were extracted in compliant patients but 5.1% in drop-out patients (Kim et al. 2014). Regardless of whether dropouts have attended SPT visits in private practice, unsatisfactory tooth retention in dropouts is confirmed by a recent publication from our group showing that SPT in private practice in Pomerania is not as effective as the university-based SPT program. Increased tooth loss rates may be also due to limitations imposed by in the German national health insurance system (Kocher et al. 2022). Trombelli et al. state that total tooth loss, and not just tooth loss due to periodontal disease, 'reflects the true magnitude of the impact of periodontal maintenance on long-term tooth survival and stability of periodontal parameters' (Trombelli, Franceschetti, and Farina 2015).

In the partially and fully compliant patients, the rebound to a higher PD at T3 is probably due to high plaque level, which determines the clinical outcome of non-surgical periodontal treatment (Tomasi et al. 2007). A very similar pattern of PD reduction as reported in our study was observed in a retrospective study of compliant patients whose average maximum PD per tooth was significantly reduced from 5.4 to 2.9 mm after APT, with a slight rebound to 3.2 mm at the 8-year examination (Konig et al. 2001). Similar changes in PD levels were observed in a randomized controlled trial conducted as part of the routine practice of a public dental clinic in Sweden to investigate different SPT intervals. Periodontal treatment reduced %PD6+ from 6% to 1%, plaque scores from 45% to 35% and bleeding scores from 55% to 35% at 5 years, irrespective of whether 3, 6 or 12 months SPT intervals were chosen (Rosen et al. 1999). By comparison, in our study, the %PD6+ decreased from 13.0% to 2.6% in partially and fully compliant patients. The partially and fully compliant patients have not attained a stable periodontal situation as defined in the S3 guideline and do not fulfil the EFP/AAP definition of a stable periodontally healthy patient. However, this study confirms a recent meta-analysis which showed that periodontal progression/tooth loss was still minimal throughout SPC without meeting stability/endpoints of therapy (Rattu et al. 2023).

Contrary to our hypothesis that drop-out patients would not benefit from periodontal treatment, their periodontal status did not return to baseline. At T3, the extent of moderate and deep pockets had been reduced by about 50%, even though they had not been under SPT for 5.2 years. It is likely that they maintained some beneficial oral hygiene habits that prevented rebound to baseline levels (Pitchika et al. 2019, 2021). Their oral hygiene habits were slightly poorer than those of the compliant patients. Our results agree with a retrospective study of dropouts from Hong Kong, where the percentage of sites with BOP decreased from 72.7% to 23.0% after APT and increased to 49.4% at re-examination 9.3 years later; %PD6+ decreased from 12.9% to 2.2% after APT and rebounded to 5.0% (Goh et al. 2017). Dropouts lost an average of 0.38 teeth per year, with only 46.2% of patients losing ≥3 teeth.

According to a recent meta-analysis, periodontal therapy improved oral health–related quality of life (Botelho et al. 2020). In our study, 40.3% of partially and fully compliant patients and 32.8% of drop-out patients rated the health of their teeth as very good or good at the final SPT examination. In line, 71.1% and 63.8% of partially and fully compliant and drop-out patients, respectively, were very satisfied or satisfied with the appearance of their teeth. In summary, these results reflect high satisfaction with oral health status even in dropouts, which was unexpected given that periodontal treatment is associated with recession and 'black' interdental triangles as a result of periodontal therapy. The latter are considered a major problem in the dental community (Singh et al. 2013).

There are several limitations of this study that need to be discussed. First, covariate data were available only at the time of T3 examination. Second, tooth extraction introduces bias in the assessment of changes in PD, as teeth with deep pockets are extracted and, thus, PD variables may be underestimated at the final examination. However, extraction of compromised teeth

TABLE 3 | Tooth loss during active and supportive periodontal therapy in partially and fully compliant and drop-out patients.

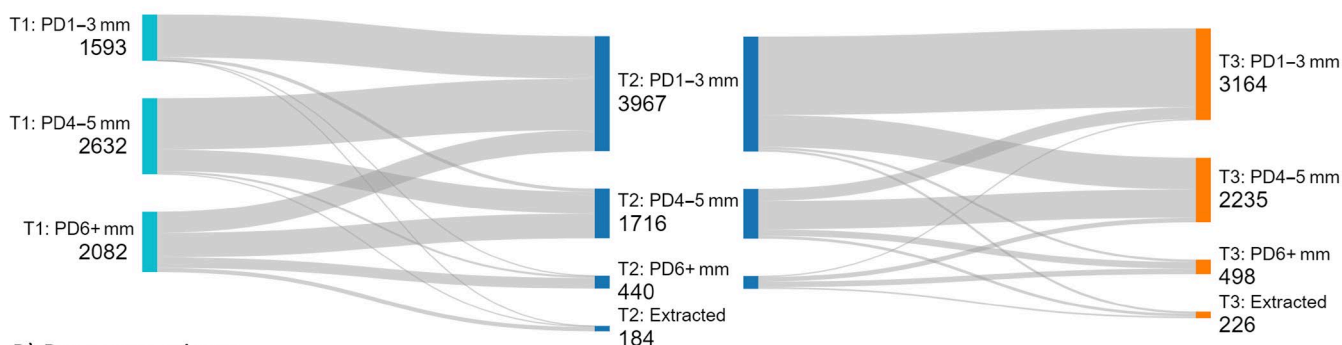|	Compliant patients	Drop-out patients	p-value
Active periodontal therapy			
Number of extracted teeth per patient	0.73 ± 1.78 \ 0 (0; 1)	0.77 ± 1.22 \ 0 (0; 1)	0.1297
Annual tooth loss per patient (N/years)	0.75 ± 2.09 \ 0 (0; 0.62)	0.98 ± 1.74 \ 0 (0; 1.22)	0.0576
Supportive periodontal therapy			
Number of extracted teeth per patient	0.74 ± 1.53 \ 0 (0; 1)	2.00 ± 2.78 \ 1 (0; 3)	0.0001
Annual tooth loss per patient (N/years)	0.19 ± 0.55 \ 0 (0; 0.18)	0.31 ± 0.50 \ 0.16 (0; 0.40)	0.0010

Note: Data are presented as mean ± standard deviation and median (25%; 75% quantiles). *p*-values were retrieved from Mann–Whitney *U* tests.
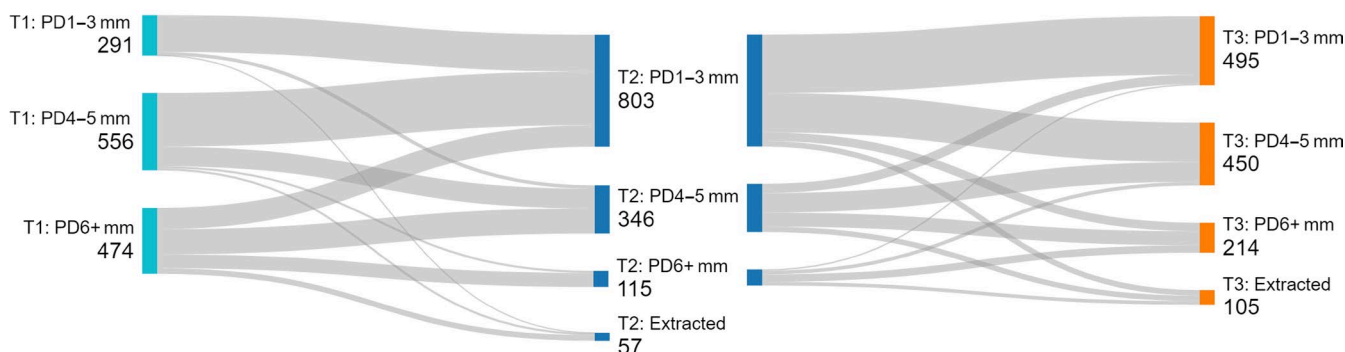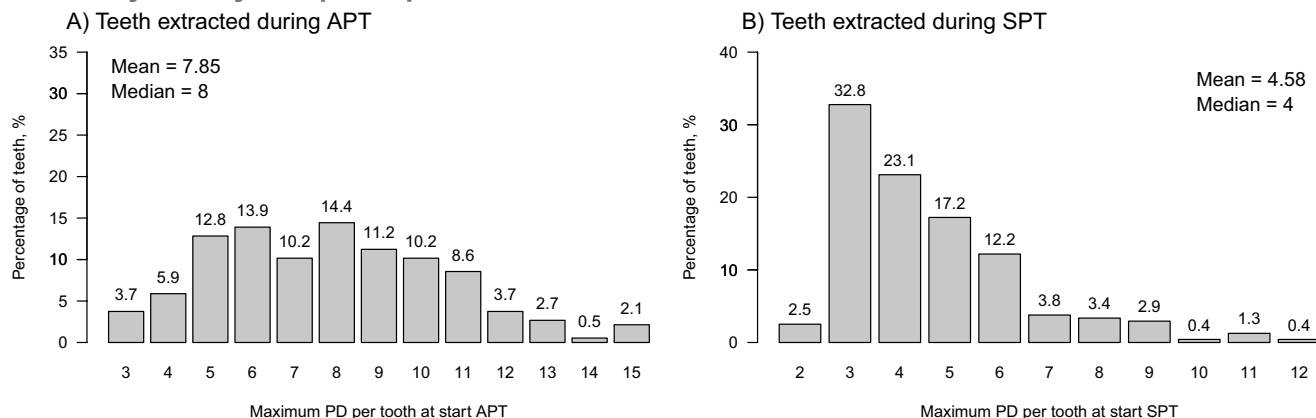

FIGURE 3 | Sankey graphs showing shifts in the number of teeth affected by probing depths (PD) of 1–3 mm, 4–5 mm, ≥6 mm or incident extraction at the start of active periodontal therapy (T1), at the start of supportive periodontal therapy (T2) and at the final examination (T3) in (A) compliant and (B) drop-out patients.

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Partially or fully compliant patients
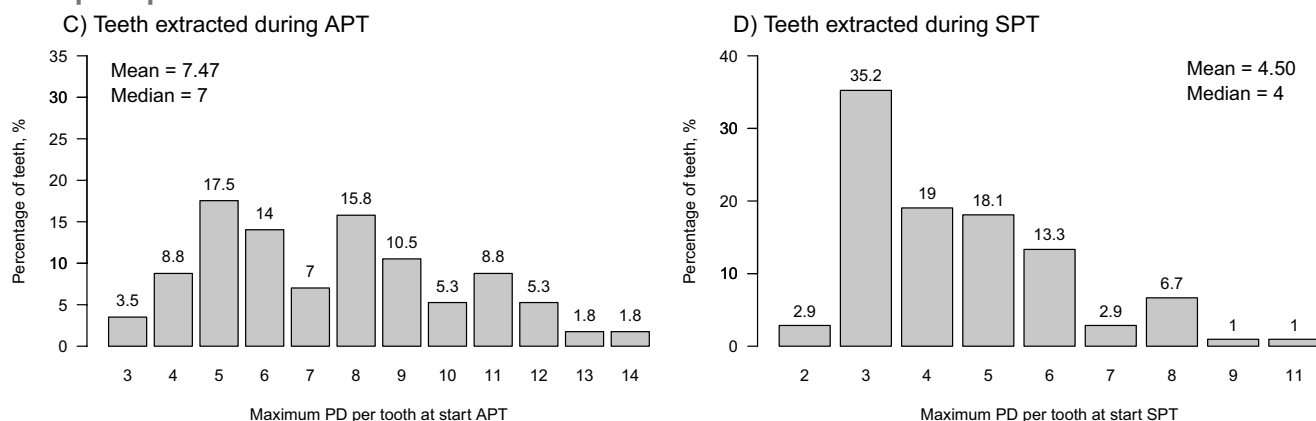

Dropout patients

FIGURE 4 | Distribution of maximum pocket probing depths (PDs) per tooth for teeth extracted during active periodontal treatment (APT; A and C) and during supportive periodontal treatment (SPT; B and D) in partially and fully compliant (top panel) and drop-out patients (bottom panel).

during APT (Figure 3) did only marginally contribute to the improvement of the periodontal status at T2 (Table 2). Second, selection bias may affect the conclusions: only 39.1% and 20.4% of eligible partially and fully compliant and drop-out patients, respectively, were analysed. The reasons for discontinuing treatment are usually thought to be lack of motivation, private reasons or low social status with an associated lack of understanding (Helal et al. 2019). Drop-out patients who agreed to be examined as part of the GANI_MED study may not be representative of the entire drop-out cohort because, as indicated by the self-rated oral health questions (Table 1), they were satisfied with treatment outcomes. Dissatisfied patients may not have attended the T3 examination, and only patients who perceived a health benefit to their periodontal status from periodontal treatment and who perceived periodontal treatment as enriching their dental education attended. As a result, tooth loss may be higher and periodontal status worse, and the benefit of APT treatment alone may be overestimated in our drop-out patients. Third, we do not have information on whether drop-out patients received SPT visits from their family dentists; a recent publication from the same catchment area, however, showed that SPT in private office is not effective (Kocher et al. 2022). Thus, even knowing whether the patients had maintenance visits in private practice would not change our conclusion. Fourth, we have no information about attachment loss, mobility or furcation involvement, which affects tooth loss and whether severity of periodontitis defined by these variables did differ between the groups.

5 | Conclusions

Dropout during SPT is a very common event in treated periodontitis patients, but the consequences and implications of dropout have not received much attention in the periodontal community. Contrary to expectations, drop-out patients retained a medium-term oral health benefit in terms of PD reduction, albeit lower than the partially and fully compliant patients, but their annual tooth loss was significantly higher than in partially and fully compliant patients. The beneficial aspects of a continuous SPT regimen probably act on preservation of teeth through non-periodontal treatment effects. Retrospective studies, however, with all their inherent problems, never provide a complete picture. The results of such a study can only be regarded as hypothesis-generating. Planned longitudinal cohort studies are needed to better understand the problem of dropout and to minimize selection bias.

Author Contributions

T.K. and B.H. substantially contributed to the conception or design of the work. T.K., K.L., C.P., B.H. and H.J.G. contributed to the acquisition, analysis or interpretation of data. T.K., K.L. and B.H. drafted the work. H.J.G. and C.P. critically revised the work for important intellectual content. All authors approved the final version of the manuscript and are accountable for all aspects of the work.

Acknowledgement

Ethics Statement

GANI_MED was positively evaluated by the ethics committee of the University of Greifswald (BB 91/10; issued 27th July 2010). All participants were informed about the study protocol and signed the informed consent and the privacy statement.

Conflicts of Interest

H.J.G. has received travel grants and speaker's honoraria from Fresenius Medical Care, Neuraxpharm, Servier and Janssen Cilag as well as research funding from Fresenius Medical Care. The other authors declare no conflicts of interest.

Data Availability Statement

Data from GANI_MED are available after data application and signature of a data transfer agreement. The data dictionary and the online application form are available at: https://transfer.ship-med.uni-greifswald.de/FAIRequest/data-use-intro. Involving a local collaborative partner to facilitate the application process is recommended.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.