Tooth Loss During Supportive Periodontal Care in a Strict Non-surgically Treated Cohort – a Retrospective Data Analysis

Valentin Bartha (valentin.bartha@med.uni-heidelberg.de)
University Hospital of Heidelberg
Judith Mohr
Private Practice
Boris Krumm
Private Practice
Marco Herz
University Hospital of Tuebingen
Diana Wolff
University Hospital of Heidelberg
Hari Petsos
Johann Wolfgang Goethe- University Frankfurt/Main

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Abstract

Background: This retrospective study aimed to evaluate tooth loss (TL) within a strict non-surgically treated patient cohort after supportive periodontal care (SPC) of 2.5-10.7 years.

Methods: Data for non-surgically treated patients were checked for: complete periodontal examination data at baseline (*T*0), after active periodontal therapy (*T*1), and after ≥2.5 years of SPC (*T*2); Smoking, diabetes mellitus, age (at least 18 years), plaque and gingival indices, bleeding on probing (BOP), percentage of residual pockets, SPC adherence, and number of SPCs were assessed as risk factors for TL.

Results: 132 patients were included (76 female, mean age 56.7±10.3 years), mean *T*1– *T*2: 4.5±1.6 years. 26.5% of all patients lost 118 teeth (0.5 teeth/patient, 0.12 teeth/patient/year). Plaque and bleeding parameters: mean plaque control record (PCR): 59.77±28.07%, mean papilla bleeding index (PBI): 47.46±34.12%, mean BOP: 33.46±21.52%. SPC duration (*p=0.013*) and *T2* BOP (*p=0.048*) were identified as patient-related risk factors for TL.

Conclusion: The strictly non-surgical approach within the reported cohort was characterized by elevated BOP, PBI, and PCR scores, possibly highlighting the lack of surgical intervention and regular SPC as negative effect. An apparently low TL rate could be observed. Duration of SPC and BOP (T2) were identified as risk factors for TL.

1. Introduction

Untreated periodontitis is a chronic inflammatory disease causing progressive attachment loss (1), possibly ending in tooth loss (TL) as true clinical endpoint (2). Studies from the last decades identified numerous risk factors for TL, including behavioral factors, such as smoking or lack of adherence to supportive periodontal care (SPC), medical factors, such as diabetes mellitus or the severity of initial periodontal diagnosis (3–5), and tooth-related factors, such as use as abutment tooth, bone loss, residual periodontal probing depths (PPDs), furcation involvement (FI), and tooth mobility (6–8).

Since the 1990s, established treatment concepts have primarily been based on supra- and subgingival non-surgical debridement added by oral hygiene instructions and training (9, 10). Currently, a three-stage therapy concept has been internationally implemented, which, after the preparatory (step 1) and non-surgical (step 2) phases, provides an optional surgical phase (step 3) before the patient is transferred to lifelong SPC (11, 12). In detail, treatment concepts have varied in the last decades, especially regarding whether, when, and which surgical approach or antibiotic drug should be used (10, 13, 14). Several long-term studies based on combined treatment concepts, including patients who were treated both non-surgically and surgically, if necessary, reported low annual TL rates of 0.09–0.21 teeth/patient up to 25 years (4, 6, 8, 15, 16).

The efficacy of reducing PPD of 4–7mm and ≥ 7mm non-surgically was demonstrated early on (17–19). Whereas flap surgery combined with osteotomy compared to non-surgical treatment for teeth with PPD between 5–6mm exhibited a small average PPD reduction of 0.5mm, other surgical methods failed to show differences after five years. For PPD ≥ 7mm, the same results were observed after six years (20).

This retrospective cohort study presents results of a strict non-surgically treated patient cohort during active periodontal treatment (APT) followed up for at least 2.5 years of SPC. It aimed to assess TL as the primary outcome variable at the Department for Conservative Dentistry at the University Hospital of Tuebingen (Germany)

and evaluate the applied non-surgical concept and expand existing evidence regarding identified patient-related factors associated with TL.

2. Material And Methods

2.1 Study design

This study is designed as a retrospective cohort study based on data analysis from patients treated between 1999 and 2015 who were identified through electronic database research at the Department for Conservative Dentistry at the University Hospital of Tuebingen. As the changeover to the electronic database took place in 1999, previous periodontal treatments were not identified. During this period, surgical therapy was not part of the periodontal treatment concept. The study protocol was approved by the University of Tuebingen Ethics committee (reference number 557/2016BO2) and was registered in the German Register of Clinical Trials (URL: https://www.drks.de; ID: DRKS00025110). An informal consent was not required for this type of study.

2.2 Inclusion criteria

The inclusion criteria include the following:

- complete periodontal examination (PPD at six sites/tooth, FI at all furcation sites of multirooted teeth (21), tooth mobility (22)) before start of therapy (baseline, *T*0) and after completion of APT (strictly non-surgical therapy) and start of SPC (*T*1);
- radiographs (panoramic radiographs or a set of periapical radiographs) not older than 12 months at *T*0;
- age ≥18 years at start of therapy (*T*0);
- no systemic antibiotic treatment during APT;
- *T*1 – *T*2 duration of at least 30 months.

2.3 Applied treatment concept

Within the period between 1999 and 2015, APT encompassed two appointments of oral hygiene instructions with professional mechanical plaque removal (PMPR), followed by either the concept of Full-Mouth Disinfection (23) or, less often, the use of povidone-iodine (24) simultaneously with subgingival instrumentation. Re-evaluation was performed regularly 3 months after subgingival instrumentation. Periodontal examination (PPD at six sites/tooth, FI at all furcation sites of multirooted teeth, tooth mobility), PMPR, and subgingival instrumentation (at sites with PPD = 4mm with BOP and PPD ≥ 5mm) were conducted. Finally, according to the periodontal risk assessment (PRA) (25), patients were assigned to SPC.

2.4 Supportive periodontal care

All treatments were conducted by dentists in collaboration with dental hygienists, dental nurses, or supervised dental students. Moreover, SPC included the following sequence:

1. Plaque control record (PCR (26)) and papilla bleeding index (PBI (27)),
2. oral hygiene remotivation and reinstruction including recommendation of individually fitting interdental brushes (Doft, Oesthammar, Sweden) and electronic toothbrushes.

3. PMPR followed by polishing with rotating rubber cups using pumice powder and Cleanic brand polish paste (Kerr GmbH, Biberach an der Riß, Germany)
4. dental and periodontal examination (PPD at six sites/tooth, FI at all furcation sites of multirooted teeth, tooth mobility),
5. subgingival instrumentation at sites with PPD = 4mm with BOP and PPD ≥ 5mm followed by instillation of 1% chlorhexidine gel (Chlorhexamed gel 1% GSK GmbH, Brentfort, UK), fluoride gel application using Elmex gelee (CP GABA GmbH, Hamburg, Germany) or Duraphat (Colgate-Palmolive, New York, USA), and
6. periodontal risk assessment (PRA) to determine the SPC interval until the next appointment.

2.5 Patient charts

Periodontal examination charts for *T*0, *T*1, and *T*2 were assessed. For each patient, BOP (%); proportion of teeth with PPD < 5mm, PPD = 5mm, and PPD > 5mm; and the number of missing teeth were documented. Moreover, mean PBI (27) and PCR (26) during SPC period were calculated. Baseline radiographs were assessed to determine the maximum interdental bone loss visually. Furthermore, charts were screened for information on current smoking status (nonsmokers, former smokers (smoking stopped at least 5 years ago), or smokers (25)) and presence of diabetes mellitus. Initial periodontal diagnoses (28) were reclassified according to the current classification (29), which was performed using maximum baseline PPD, bone loss, presence of diabetes mellitus, smoking status and TL. The grade was assigned based on the bone loss age index and upgraded according to the diabetic and/or smoking status. An SPC frequency of at least 2 visits per year was considered as adherent.

2.6 Statistical analysis

The patient was considered a statistical unit. Overall TL during SPC (*T*1 – *T*2) was considered the primary outcome variable and was calculated by subtracting the number of teeth. All other parameters were considered secondary outcome variables. The descriptive data were calculated as absolute or relative frequencies and mean (± standard deviation). Mean values and frequencies were compared using a paired *t*-test or chi-square test.

Negative binomial regression analysis was performed to identify factors influencing TL during SPC. The variables (a) grading, (b) duration of SPC, and (c) relative distribution of PPD at *T*0 and (d) at *T*1 exhibited significant bivariate correlations with TL during SPC and were consequently put into the model. Third molars were excluded from the data analysis. A significance level of 0.05 was assumed. All statistical analyses were performed using computer software (IBM SPSS® Statistics 24 software package, IBM, Chicago, IL, USA).

3. Results

A total of 573 patient files was screened for eligibility. Thereof 441 were dropped out due to incomplete baseline periodontal status (*n* = 106), a follow-up period less than 30 months (*n* = 310), age < 18 years at start of therapy (*n* = 1) or systemic antibiotic treatment during APT (*n* = 24) (Figure 1).

3.1 Baseline characteristics

In total, 132 patients (76 females, 56 males) with an average age of 56.7±10.3 years were included in the study. About 27% (*n* = 36) of all patients were smokers, and 9% (*n*=12) were suffering from diabetes mellitus. The average duration of SPC was 4.5±1.64 (range: 2.5–10.7) years. All patients showed a stage III periodontitis, most of them in grade B (*n* = 88, 66.7%).

At start of SPC, patients with TL were older compared to patients without TL (on average 0.5 years older, *p=0.071*). The relative proportion of smokers was higher when TL occured (*p=0.494*) as for patients with diabetes (*p=0.901*). Overall, 93% of patients were identified as non-adherent. The mean SPC interval was longer in patients with TL than in those without TL, yet the difference was not statistically significant (with TL: 15.55 months; without TL: 12.61 months, *p=0.253*) (Table 1). Moreover, 7 patients were non-surgically treated with povidone-iodine simultaneously with subgingival instrumentation.

Table 1

Patient characteristics

	Overall	with TL	without TL	*p*
	n (%)	n (%)	n (%)	
Number of patients	132	35	97	*<0.0001*
Female/male	76/56 (58/42)	20/15	56/41	*0.952*
Age (T1)	56.65 ± 10.30	57.05 ± 7.63	56.51 ± 11.14	*0.071*
Smoker (T1)	36 (27)	8 (6.1)	28 (21.2)	*0.494*
Diabetes (T1)	12 (9)	3 (2.3)	9 (6.8)	*0.901*
PRA (T1)				
Low	15 (11.4)	1 (0.8)	14 (10.6)	*0.110*
Moderate	70 (53.0)	18 (13.6)	52 (39.4)	
High	47 (35.6)	16 (12.1)	31 (23.5)	
Duration of SPC				
3 years ± 6 months	52 (39.4)	11 (8.3)	41 (31.1)	*0.092*
4 years ± 6 months	31 (23.5)	5 (3.8)	26 (19.7)	
5 years ± 6 months	9 (6.8)	4 (3.0)	5 (3.8)	
> 5.5 years	40 (30.3)	15 (11.4)	25 (18.9)	
SPC				
Adherent	9 (7)	0 (0)	9 (6.8)	*0.062*
Non-adherent	123 (93)	35 (26.3)	88 (66.7)	
Mean number of visits	6.32 ± 2.65	6.54 ± 3.03	6.31 ± 2.52	*0.657*
Mean SPC interval	13.39 ± 12.98	15.55 ± 17.60	12.61 ± 10.87	*0.253*
Mean duration of SPC (months)	52.32 ± 18.38	57.82 ± 19.05	50.34 ±17.82	*0.039*
Initial diagnosis				
Stage III	132 (100)	35 (26.5)	97 (73.5)	*<0.0001*
Grade A	5 (3.8)	3 (2.3)	2 (1.5)	*0.163*
Grade B	88 (66.7)	24 (18.2)	64 (48.5)	
Grade C	39 (29.5)	8 (6.1)	31 (23.5)	
TL APT (mean, range)	0.46 ± 1.37 (0–10)			
TL SPC (mean, range)	0.54 ± 1.41 (0–11)			

TL=tooth loss, APT=active periodontal therapy, SPC=supportive periodontal care, BOP=bleeding on probing,

PRA=periodontal risk assessment

3.2 Clinical parameters and tooth loss

Percentage distributions of clinical parameters, PPD, and BOP for each follow-up re-examination and mean PCR and PBI during SPC are presented in Table 2. In all groups, an increase in PPD < 5mm in favor of a decrease in PPD ≥ 5mm from *T*0– *T*1 and *T*0– *T*2 can be observed for the relative distribution of PPD. Mean BOP and PCR values during SPC were lower in patients without TL.

Table 2

Descriptive data for PPD, BOP, mean maximum Boneloss, mean PCR and PBI on patient level according to TL

	PPD (%) <5 (mean±SD)			PPD (%) =5 (mean±SD)			PPD (%) >5 (mean±SD)		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
Overall	86.95 ± 8.58	93.72 ± 6.51	91.02 ± 10.09	6.38 ± 3.87	3.53 ± 4.09	5.07 ± 5.36	6.68 ± 6.42	2.75 ± 3.43	3.01 ± 5.58
without TL	87.36 ± 8.44	93.90 ± 6.91	90.72 ± 10.90	6.60 ± 3.83	3.60 ± 4.28	5.26 ± 5.63	6.03 ± 6.01	2.50 ± 3.44	4.02 ± 6.01
with TL	85.78 ± 8.99	93.23 ± 5.31	91.85 ± 7.64	5.76 ± 3.93	3.33 ± 3.55	4.57 ± 4.58	8.46 ± 7.24	3.43 ± 3.16	3.58 ± 4.24
p	*0.352*	*0.606*	*0.573*	*0.268*	*0.743*	*0.520*	*0.055*	*0.163*	*0.688*
	BOP (%) (mean±SD)			Mean PBI (%) (mean±SD)			Mean PCR (%) (mean ±SD)		
	T0	T1	T2	during SPC			during SPC		
Overall	42.26 ± 29.79	30.13 ± 30.09	31.83 ± 25.79	47.46 ± 34.12			59.77 ± 28.07		
without TL	39.33 ± 29.80	28.16 ± 28.59	29.66 ± 23.14	49.20 ± 34.06			62.29 ± 26.99		
with TL	50.40 ± 28.59	35.58 ± 33.75	37.84 ± 31.62	42.64 ± 34.12			52.78 ± 30.19		
p	*0.059*	*0.213*	*0.108*	*0.331*			*0.086*		
	Mean BOP (%) (mean±SD)						Mean maximum Boneloss (%) (mean±SD)		
	during SPC								
Overall	33.46 ± 21.52	30.13 ± 30.09	31.83 ± 25.79				45.27 ± 20.07		
without TL	32.47 ± 20.87	28.16 ± 28.59	29.66 ± 23.14				45.72 ± 19.87		
with TL	36.22 ± 23.35	35.58 ± 33.75	37.84 ± 31.62				44.00 ± 20.86		
P	*0.059*	*0.213*	*0.108*				*0.657*		

TL=tooth loss, PPD= periodontal pocket depth, BOP=bleeding on probing, PCR=plaque control record, PBI=papilla bleeding index, SD=standard deviation

Analysis of TL revealed that 26.5% (*n* = 35) of all patients lost between 1–11 teeth during SPC. Overall, 71 teeth were lost during SPC. Two of these patients lost 20 teeth overall, more than one-quarter of all TL. Regarding grades A–C, in grade B, 24 patients lost the majority of 46 teeth overall, whereas 8 patients with grade C lost 11

teeth overall, and three patients with grade A lost 13 teeth overall, which was the highest proportion. The relative proportion of patients with TL increased with a longer SPC period from 20–40% (Table 3).

Table 3
Number of lost teeth during SPC according to grading, duration of SPC and Number of SPC visits per year

Number of lost teeth (n)	Number of patients (n, %)	Grade A (n, %)	Grade B (n, %)	Grade C (n, %)	Duration of SPC				Adherence	
					2.5–3 years (n, %)	4 years (n, %)	5 years (n, %)	> 5.5 years (n, %)	Non adherent (n, %)	Adherent (n, %)
	n= 132	n=5	n=88	n=39	n=52	n=31	n=9	n=40	n=123	n=9
0	97 (73.5)	2 (40)	64 (72.7)	31 (79.5)	41 (78.9)	26 (83.9)	5 (55.6)	25 (62.5)	88 (71.5)	9 (100)
1	20 (15.2)	2 (40)	13 (14.8)	5 (12.8)	5 (9.6)	4 (12.9)	4 (44.4)	7 (17.5)	20 (16.3)	0 (0)
2	8 (6.1)	0 (0)	6 (6.8)	2 (5.1)	2 (3.9)	1 (3.2)	0 (0)	5 (12.5)	8 (6.5)	0 (0)
3	5 (3.8)	0 (0)	4 (4.6)	1 (2.6)	3 (5.8)	0 (0)	0 (0)	2 (5)	5 (4.1)	0 (0)
9	1 (0.7)	0 (0)	1 (1.1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.5)	1 (0.8)	0 (0)
11	1 (0.7)	1 (20)	0 (0)	0 (0)	1 (1.8)	0 (0)	0 (0)	0 (0)	1 (0.8)	0 (0)

SPC=supportive periodontal care, n=number of patients/teeth

Bivariate analysis of independent variables on TL revealed no significant correlations for gender, diabetes, smoking, bone loss, adherence to SPC, duration of SPC, number of SPC appointments, age, PLI or PCR, but for Grading, percentage of sites with PPD ≥ 6mm at T0 and BOP at T2.

Binominal negative regression analysis revealed a statistically significant negative correlation for grade C (*p=0.041*) and a significant positive correlation for SPC duration (*p=0.013*) and proportion of sites with BOP at T2 (*p=0.048*) (Table 4).

Table 4
Negative binominal regression analysis: TL during SPC according to different risk factors

Parameter	Regression coefficient	*p*	Incidence rate ratio (IRR)	95% CI (IRR)	
				Lower CI	Upper CI
Constant	-2.057	*0.025*	0.128	0.021	0.775
Grade C	-1.379	*0.041*	0.252	0.067	0.947
Grade B	-0.864	*0.18*	0.421	0.119	1.489
Grade A	Reference				
Duration SPC	0.021	*0.013*	1.021	1.004	1.038
PPD≥6 (T0)	0.041	*0.096*	1.041	0.993	1.093
PPD=5 (T0)	0.053	*0.15*	1.055	0.981	1.134
PPD<5 (T0)	Reference				
BOP (T2)	0.012	*0.048*	1.012	1.000	1.024
PPD= periodontal pocket depth, SPC=supportive periodontal care, CI=confidence interval					

4. Discussion

In this retrospective cohort study on strictly non-surgically treated periodontally compromised patients within a mean SPC period of 4.5±1.64 years, 26.5% of all patients lost 118 teeth overall, resulting in a TL rate of 0.5 teeth/patient and 0.12 teeth/patient/year. The majority of teeth were lost in cases with grade A and B and with longer duration of SPC. SPC duration and relative proportion of BOP at T2 were identified as patient-related risk factors for TL. For all other risk-factors we found no statistically significant correlation with TL. In general, the study shows the positive effect of a strictly non-surgical therapeutic approach, but also allows the indirect conclusion that better therapeutic results could have been achieved if the international clinical practice guidelines for treatment of stage I–III periodontitis would have been applied (11).

Comparing the annual overall TL rate with studies with similar observation periods, lower to same annual TL rates of 0.06 –0.17 teeth/patient were reported (30–32). A prospective study over five years reported a TL rate of 0.12 teeth/patient/year for an adherent subgroup of 96 patients, which is also in line with the overall results of our study. Within the same study, 116 non-adherent patients demonstrated a significantly higher TL rate of 0.36 teeth/patient/year (33). This result is threefold higher than the overall findings in the present study and is comparable to nontreated periodontal patients with a reported periodontal TL rate of 0.33 teeth/patient/year over 40 years (2). However, due to the low number of adherent patients in the present patient cohort, further subanalyses were dispensed with.

Studies with observation periods of 10 years reported annual TL rates of 0.12–0.21 teeth/patient (6, 7, 34–37), and for periods of 17–25 years, annual TL rates of 0.09–0.14 teeth/patient were documented (15, 16, 38). However, these studies with longer SPC periods are not comparable to the present study due to increasing TL rates within longer observation periods (8, 16). A minority of 7 patients lost 50% of all teeth within the present cohort, which is also concordant with other studies (7, 39–43).

The present study was unable to reconfirm some well-known risk factors for TL. The correlation of age with TL and the higher average *T*1 age for patients with TL (57.1 years) compared to patients without TL (56.5 years) were not statistically significant. Generally, age has been confirmed several times as a risk factor for TL during SPC (16, 30, 35, 39, 42). This result might become even clearer through data from a long-term study over 20 years, where an increasing TL rate within the second 10 years (1.67 teeth/patient) is reported compared to the first 10 years (1.2 teeth/patient), with a moderate positive correlation between both (Pearson's $r = 0.492$) (16).

Mean SPC interval of the present study was 13.39 months, with a longer interval of 15.55 months for patients with TL compared to patients without TL at 12.61 months. Consequently, only 9 patients (7%) were adherent to SPC. SPC duration was statistically significantly longer for patients with TL (57.82 months) compared to those without TL (50.34 months) (p=0.039). The average number of SPC visits per year was 1.29 for all patients. Petsos et al. reported an average of 2.25 SPC visits per year over 10 years. Within this study, 58% of patients were classified as adherent according to a risk-adapted definition of adherence based on the PRA (35), and this group had a higher TL rate (7). In the present study, the lower number of 1.29 visits per year for overall patients results from the high number of non-adherent patients (93%) within the cohort. Petsos et al. suggests the slightly higher number of SPC visits in patients with TL can be considered a result of higher periodontal risk according to PRA, resulting in a shorter SPC interval recommendation. Due to the low proportion of 7% adherent patients in our study, this observation cannot be sufficiently compared. Moreover, in contrast to other studies (7, 8, 16, 33, 35), SPC adherence was not identified as risk factor for TL, which might also result from the low number of adherent patients in the study (44).

Since all patients suffer from stage III periodontitis, the stage itself could not be analyzed as a risk factor for TL. A low number of patients at grade A (3.8%) and a majority at grades B (66.7%) or C (29.5%) was found. Grading was not identified as risk factor for TL. Surprisingly patients with grade A or B lost more teeth compared to patients with grade C. An explanation could be that in each group (grade A and B) one single patient lost 11 teeth (A), 9 teeth (B) resp., indicating that this might be a result of a prosthetic planning and not for periodontal reasons. In general, a retrospective determination of reasons for TL is difficult. Especially TL for periodontal, prosthetic, endodontic or restorative reasons highly depends on individual dentists´ decision biased by differences in experience and knowledge of appropriate evidence. To date, there is no uniform definition for periodontal TL. On the other hand, SPC should primarly prevent TL for periodontal reasons, but not only. We found that maximal bone loss didn´t correlate with TL, which could indicate a high proportion of TL for non-periodontal reasons within the observed cohort. Bone loss (8, 15, 30), smoking (7, 16, 33, 42, 45), and diabetes (16, 33) were associated with increased TL in several studies. In the present study, 12 smokers lost 26 teeth, and four people with diabetes lost 12 teeth. However, both factors could not be identified as risk factors for TL.

Some authors have reported individual plaque control as risk factor (16, 35). The present study found a mean PCR of 52.78% during SPC in patients with TL and 62.29% in those without TL. Hence, PCR was not identified as a risk factor for TL. In accordance with these PCR values, PBI was 42.64% (with TL) and 49.2% (without TL), and mean BOP values remained at 33.46±21.52% during SPC. Moreover, BOP at T2 correlated statistically significant with TL and indeed, this is a high degree of residual gingival and periodontal inflammation, which might result from the low annual SPC frequency mentioned above or the lack of surgical therapy. For BOP at sites $\leq$ 4mm, an odds ratio (OR) of 1.9–2.1 has been reported, with an increasing OR of up to 43.6 for PPD $\geq$ 7mm (46). These data might also indicate an increased risk for further TL in a longer observation period within the present cohort. An oral-optimized healthy diet (47–49) or a paleo-type diet (50) has been shown to reduce periodontal bleeding

parameters even in presence of plaque. Diet interventions could be an additional strategy for inflammation control in the future. Currently, more evidence regarding its efficacy is necessary (11). However, no data on nutrition were collected in this study.

In contrast to the SPC interval, the duration of SPC has been shown to correlate with TL. This result is related to the significantly higher age of patients with TL, as previously explained, which is in line with previous studies (6, 42). It seems plausible that more teeth are lost the longer the observation period increases. For this reason and the SPC range of 2.5–10.7 years in this cohort, the statistical model was adjusted for the SPC duration.

Overall, the decrease in PPD ≥ 5 mm from *T*0– *T*1 and *T*0– *T*2 indicates the efficacy of non-surgical therapy. Increased Baseline PPD were not identified as significant risk factor for TL. As mentioned, this could be another indication that decisions for extraction were predominantly not based on periodontal parameters. Moreover, the results generally indicate higher proportions of residual pockets compared to other findings reported in both subgroups: a proportion of 3.5% (adherent) and 4.1% (non-adherent) with a PPD of 4 to 5mm, and 0.9% (adherent) and 1.5% (non-adherent) with PPD ≥ 6 mm (33). In contrast to the present study, Costa et al. consequently performed surgical treatment of residual pockets before SPC, resulting in a lower TL rate, which underlines the positive effect of surgical therapy as a complement to a primary non-surgical approach.

Over 11 years, an OR of 9.3 for TL has been reported for residual PPD of 6mm and 37.9 for a PPD ≥ 7mm (46). Petsos et al. found a 1.5% proportion of sites with PPD ≥ 6mm at *T*1 and 1.9% at *T*2 with lower proportions in the group without TL (7). Considering these findings, the higher proportions of residual pockets at *T*1 within the present population and the reported OR values for TL, it seems plausible that TL increases within a longer observation period. Recently published guidelines (11, 12) recommend a surgical approach in cases with PPD ≥ 6mm. Increased residual pockets, bleeding, and plaque levels in a strict non-surgically treated cohort seem to support these recommendations.

This study has limitations, which should be critically addressed. First, this study has a shorter observation period compared to most recently published studies. Second, due to the lack of documentation of recessions and clinical attachment loss (CAL), no information on CAL development could be reported. Third, two non-surgical approaches were re-examined, possibly leading to a bias. Fourth, due to the retrospective nature of the study, TL in general and for periodontal reasons could not be distinguished, partly as a result of decisions for extraction by dentists in different fields and the high frequency of changing therapists during SPC. Fifth, since all of the patients included suffered from moderate periodontitis at the beginning of therapy, comparability with most studies is limited.

5. Conclusions

Even if the low TL rate of this cohort with stage III periodontitis patients, which was treated strictly in a non-surgical way, is comparable with other cohorts that have also been surgically treated if necessary, a comparatively increased gingival and periodontal inflammation status is particularly evident. This possibly highlights the negative effect of the largely lack of adherence and/or the lack of a surgical approach. Duration of SPC and relative proportion of BOP at T2 were identified as risk factors for TL.

Declarations

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Not applicable

Author contributions

All authors contributed substantially through drafting, data interpretation, and critical revision of the paper. Moreover, they approved the final version of the paper and agreed with all aspects of the work. Additionally, JM and BK collected the data; MH and VB conceived the study design; and HP analyzed the data statistically and led the writing process.

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Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was approved by the University of Tuebingen Ethics committee (reference number 557/2016BO2). Written informed consent was not required for this type of study.

Consent for publication

All authors consent for publication.

Competing interests

The authors declare no conflicts of interest

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Figures

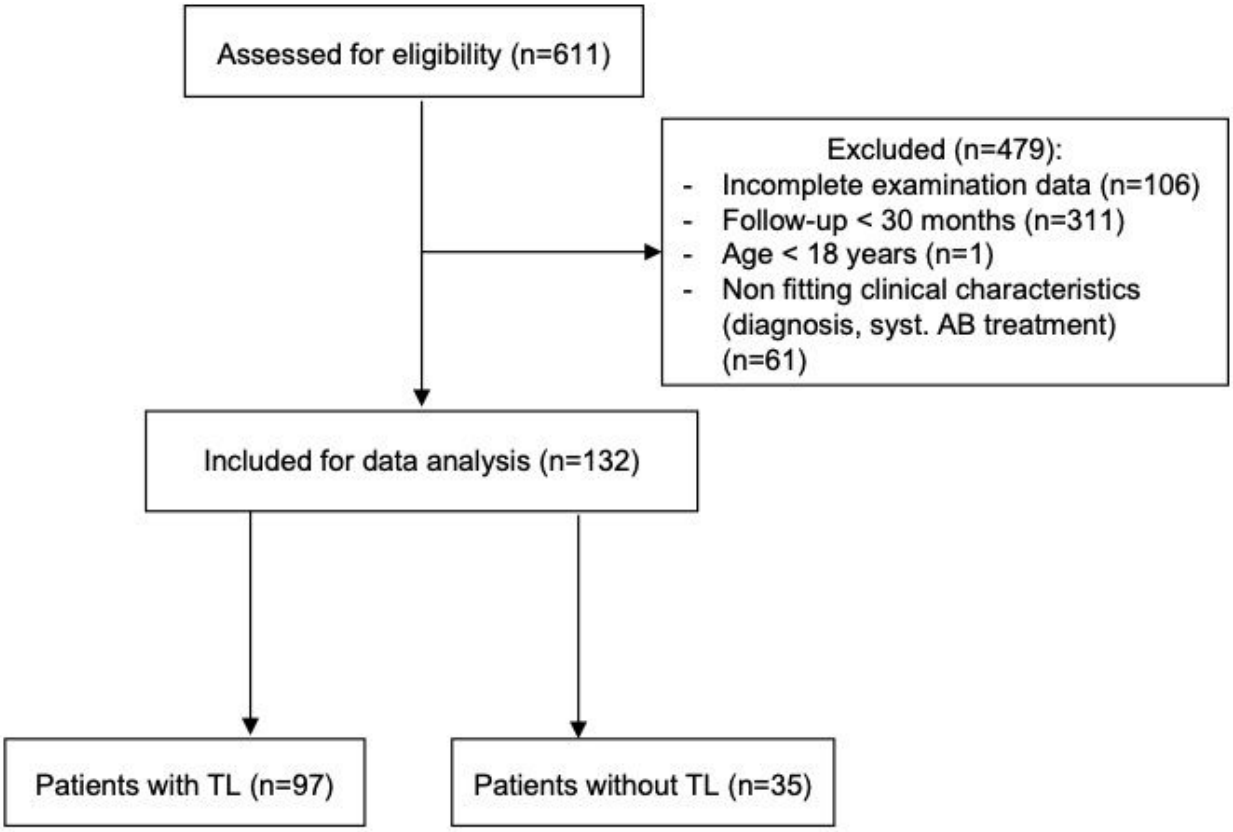

Figure 1

Patient flow chart (TL=tooth loss)