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Tooth loss in compliant and non-compliant periodontally treated patients: 7 years after active periodontal therapy

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Abstract

Aims: To investigate the incidence and reasons for tooth loss during active periodontal therapy (APT) and periodontal maintenance (PM) in a specialist institution.

Material and methods: Retrospective data were collected from 273 patients [all compliers (AC)] and cross-sectional data from 39 patients after discontinuation of PM [non-compliers (NC)] for at least 7 years after APT. Descriptive statistics and regression analysis were performed. A comparison was made between AC and NC. The prognostic factors associated with tooth loss during PM were identified.

Results: AC lost 1.3 teeth/patient during APT and 0.9 teeth/patient during PM (mean 10.7 years). Tooth loss due to periodontitis was 0.03 teeth/patient/year. The age of $\geqslant 60$ was a significant predictor of tooth loss during PM (odds ratio of 2.1). NC lost 1.1 teeth/patient during APT and 2.7 teeth/patient during discontinuation (mean 9.6 years). Tooth loss due to periodontitis was 0.22 teeth/patient/year, a sevenfold increase ($p < 0.05$) compared with AC. Regression analysis failed to identify any significant predictors for tooth loss during the discontinuation of PM.

Conclusions: In this study, the provision of PM led to minimal tooth loss, especially due to periodontitis, for a mean period of 10 years after APT. The completion of APT without PM may predispose patients to lose more teeth compared with patients who undergo PM.

Key words: extraction; periodontal disease; periodontal maintenance; periodontitis; tooth loss

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The main objectives of periodontal therapy are to control periodontal infection and inflammation, and to halt the progression of attachment loss, thereby preventing eventual tooth loss. It is also the aim of therapy to ensure the long-term retention of natural teeth in a healthy, functional, aesthetically acceptable and painless state (Hirschfeld & Wasserman 1978).

The provision of active periodontal therapy (APT) or initial cause-related therapy, followed by periodontal maintenance (PM) has demonstrated predictable long-term stability and improvements of the periodontium (Knowles et al. 1979, Axelsson & Lindhe 1981, Pihlström et al. 1983, Lindhe & Nyman 1984, Ramfjord et al. 1987, Kaldahl et al. 1996, Axelsson et al. 2004). Attachment loss (Joss et al. 1994, Kaldahl et al. 1996, Axelsson et al. 2004), recurrence of pockets (Carnevale et al. 2007a, Matuliene et al. 2008) and tooth loss (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989, Hujoel et al. 2000, Tonetti et al. 2000, König et al. 2001, Checchi et al. 2002, Fardal et al. 2004, Muzzi et al. 2006, Faggion et al. 2007, Carnevale et al. 2007a, b, Eickholz et al. 2008, Matuliene et al. 2008, Miyamoto et al. 2010) rarely occur in patients regularly attending PM. It has been reported that only a small group of

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patients regularly attending PM will actually lose more teeth after the completion of APT (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Nabers et al. 1988, Wood et al. 1989, Tonetti et al. 1998, 2000). The absence of maintenance following periodontal treatment is associated with significantly higher rates of tooth loss (Kocher et al. 2000).

Despite the evident benefits of a maintenance programme, only a minority of patients comply with the prescribed recommendations (Wilson et al. 1984, Mendoza et al. 1991, Checchi et al. 1994, Demetriou et al. 1995). Compliance of PM has been classified as regular, irregular and non-compliance (Novaes et al. 1996). There are very few studies that have evaluated the difference in treatment outcomes (in terms of tooth loss during PM) in these three groups of patients (Kocher et al. 2000, König et al. 2001).

A review of the available literature showed that periodontitis-susceptible patients who comply with a regular maintenance programme after the completion of APT had a low level of combined tooth loss and tooth loss due to periodontitis during PM (Oliver 1969, Hirschfeld & Wasserman 1978, McFall 1982, Lindhe & Nyman 1984, Goldman et al. 1986, Wood et al. 1989, McGuire 1991, McLeod et al. 1997, Tonetti et al. 2000, König et al. 2002, Fardal et al. 2004, Leung et al. 2006, Faggion et al. 2007, Carnevale et al. 2007b, Eickholz et al. 2008). The tooth loss due to periodontitis in these studies ranged from 0.01 to 0.14 teeth/patient/year. A recently published systematic review found that the percentages of tooth loss due to periodontal reasons varied from 1.5% to 9.8% (Chambrone et al. 2010). Age, smoking and initial tooth prognosis were found to be associated with tooth loss during PM (Chambrone et al. 2010).

Most of the retrospective studies reported on patients who had attended PM throughout the entire period before re-examination. However, in order for the effect of PM to be revealed, a control group of non-compliant patients (those who discontinued treatment after APT) is required (Eickholz et al. 2008). Only one study reported on a group of patients who were treated for periodontal disease but elected not to participate in the maintenance treatment (Becker et al. 1984a). After adjusting for teeth that had a hopeless prognosis at the first examination, the mean tooth loss was 0.22 teeth/patient/year. The causes of tooth loss were not limited to periodontal reasons only. The results of this study suggested that treatment without maintenance is of questionable value in terms of maintaining periodontal health. Comparing the data from the earlier studies (Becker et al. 1984a, b) as well as long-term retrospective studies (Hirschfeld & Wasserman 1978, McFall 1982, Goldman et al. 1986, Wood et al. 1989), the completion of APT without PM resulted in twice the number of tooth extractions as compared with patients who were placed on PM.

Several studies have analysed tooth loss both during APT and PM in the same group of patients (McLeod et al. 1997, Tonetti et al. 2000, Checchi et al. 2002, König et al. 2002, Faggion et al. 2007, Carnevale et al. 2007b, Eickholz et al. 2008, Matuliene et al. 2008), where information would be pertinent for elucidating the impact of APT and/or PM in the treatment of periodontitis. The impact of patients' compliance during PM on tooth survival still remains controversial due to the lack of data. There are limited studies that have evaluated tooth loss in patients who received APT but were not maintained subsequently (Becker et al. 1984a, Leung et al. 2006). In order to evaluate the effect of PM, a control group of non-compliant patients is required. However, the intentional inclusion of periodontitis-susceptible patients without rendering PM in research studies would have raised ethical concerns. Hence, there is still insufficient evidence to substantiate that placing patients on PM after APT can indeed lead to retention of teeth (true endpoint) when compared with those who did not receive PM.

Thus, the aims of this study were (1) to investigate the incidence and reasons for tooth loss (true endpoint) during APT and PM in a group of patients on PM and in another group of patients who discontinued PM for at least 7 years or more, (2) to investigate the impact of compliance (classification by Novaes et al. 1996) on tooth loss and (3) to identify the prognostic factors associated with tooth loss during PM/discontinuation of PM in both groups of patients.

Material and Methods

This study comprised of two parts – a longitudinal retrospective study and a clinical recall cross-sectional study.

Patients

The retrospective study consisted of patients with chronic periodontitis treated by periodontists at the Department of Restorative Dentistry, National Dental Centre Singapore (NDCS). These patients comprised the all compliers (AC) group – they had received APT and were subsequently placed on a maintenance programme at the centre for at least 7 years. They are still currently undergoing PM at the centre. The AC group was divided into: (1) regular compliers (RC) and (2) irregular compliers (IC) (Novaes et al. 1996).

The cross-sectional study consisted of patients who were seen between March 1997 and December 1998, inclusive, at NDCS, but discontinued PM after the completion of APT. These patients dropped out before the commencement of PM at NDCS for at least 7 years after the last periodontal appointment and they constituted the ''non-compliers'' (NC) group (Novaes et al. 1996).

Exclusion criteria included incomplete or deficient clinical and radiographic records, patients with systemic conditions that contraindicated extractions (e.g., received head and neck radiotherapy, patients on intravenous bisphosphonates) and patients who had been on PM or had discontinued PM for <7 years.

Data extraction

Patients who were treated by periodontists before December 1997 in NDCS were identified from the electronic patient database. The principal investigator (N. C. H. M.), who was not involved in the clinical treatment of these patients, retrieved and reviewed these patient folders. Relevant data were obtained from the case notes/charts/radiographs of patients who met the inclusion criteria and the information entered into data collection forms.

The study was approved by the Institutional Review Board for Human Studies of the National Dental Centre Singapore (Application # 07/07-08).

Periodontal treatment

At baseline, all patients had received a comprehensive periodontal examination and treatment planning. Appropriate radiographs were taken and bone loss was evaluated. All patients received similar periodontal treatment, which included non-surgical therapy and surgical intervention when indicated. APT

included scaling and root planing, minor occlusal adjustments, removal/finishing of overhang/defective restorations and reinforcement of oral hygiene. Systemic antibiotic therapy (e.g., amoxicillin and/or metronidazole) was prescribed in patients with acute abscess or exacerbation of periodontal disease. After the completion of APT, patients were placed on a PM programme at the NDCS. During the PM appointment, update of the medical and dental histories, re-examination of the periodontal status, debridement, polishing of teeth and application of topical fluorides were routinely performed. Sites that showed signs of disease activity, i.e., exudate with worsening probing depths were treated with repeated scaling and root planing.

Evaluation of patients' charts

Information obtained from the record folders included patient-related information (age at the start of APT, gender, compliance, self-reported systemic condition such as diabetes mellitus, smoking, number of teeth present at the initial visit, initial periodontal diagnosis) and tooth-related information (timing and reasons for tooth loss).

The number of teeth present was determined at three time points: initial examination and consultation, end of APT and the most recent PM appointment visit (clinical recall appointment for the NC). The number and type of teeth lost, including erupted third molar, during active therapy was assessed by comparing the baseline examination (before the commencement of APT) with the first PM examination. The erupted third molars were included so as to allow an accurate assessment of the extent and reason for extraction (if any) during APT and PM. Tooth loss during PM was assessed by comparison of the first PM examination with the most recent PM visit. Tooth loss during discontinuation of PM was assessed by comparison of the last APT examination with the most recent clinical recall. The reasons for tooth loss as noted from the records included periodontal disease, non-vitality, failed endodontics, periodontal–endodontic lesions (primary periodontal, secondary endodontic lesions with marked clinical probing depths and severe radiographic bone loss), caries/non-restorability, crown/root fracture, prosthetic considerations, non-functional, impaction and orthodontics. Teeth considered extracted due to periodontal reasons included signs and symptoms of periodontal disease (deep probing depths, bone loss, class III furcation involvement, mobility, periodontal abscess, suppuration), compromised function and comfort of the patient.

Clinical recall examination of NC

All examinations were performed by an independent examiner (N. C. H. M.) and included the following information: number, type, timing and reasons for tooth loss, self-reported systemic condition such as diabetes mellitus, smoking characteristics (type, duration, dose), reasons for discontinuation of periodontal therapy (e.g., time, cost, did not perceive need for treatment and fear of treatment).

Classifications

Periodontal diagnosis was classified according to the American Academy of Periodontology guidelines (Armitage 1999). Severity is based on the amount of clinical attachment loss (CAL) and is designated as mild (1–2 mm CAL), moderate (3–4 mm CAL) or severe ($\geqslant$5 mm CAL). It is classified as localized if the affected sites are 30% or less and generalized if there are more than 30% affected sites. Compliance was classified according to Novaes et al. (1996). RC were those who attended at least two-thirds of the prescribed appointments. IC were those who attended less than two-thirds of the prescribed appointments of PM. NC were those who discontinued treatment after the completion of APT. Smokers were categorized as light smokers (1–9 cigarettes/day), moderate smokers (10–19 cigarettes/day), heavy smokers ($\geqslant$20 cigarettes/day) and ex-smokers (stopped smoking for $\geqslant$1 year).

Statistical analyses

All data collected were entered in a computer database using Excel spreadsheet and analysed using a statistical software package (SPSS 17.0). The main outcome variable was the mean number of teeth lost during APT and PM. We postulated that the difference in the mean tooth loss between the groups (AC and NC) is 2, with an SD of 2.5; this will require 35 subjects in each group for a power of 90% and a two-sided test of 5% to achieve statistical significance. The differences in the primary outcome between the groups were analysed using parametric tests if normality and homogeneity assumptions were satisfied; otherwise, the non-parametric Mann–Whitney *U*-test was applied. The associations between categorical variables were assessed using χ^2- or Fisher's exact tests with odds ratios presented where applicable. Significance was set at $p < 0.05$.

Unless specified, the patient was the unit of analysis. To correct for confounding factors, multivariate regression analysis was performed to identify the factors that influenced the dependent variable tooth loss during PM for the RC and IC groups as well as during the discontinuation of PM for the NC group. Variables entered into the model were segregated into patient-related factors (age, gender, diabetes, initial periodontal diagnosis, number of teeth present at initial visit, compliance with the recommended PM attendance). The multivariate models allow and adjust for the correlation of the variables in the same patient. After the identification of dichotomous factors, the means, standard deviations, medians and ranges for tooth loss of the respective groups were calculated and presented.

Results

Patients

For the retrospective group, 478 treatment folders were reviewed and 273 patients met the criteria of AC. AC consisted of 239 RC and 34 IC who had completed APT and were subsequently placed on a PM programme. For the cross-sectional group, after reviewing 1318 treatment folders, 207 patients met the criteria for NC and were invited to join the study by letters of invitation. Only 39 patients agreed and returned for the clinical recall. The demographics of the subjects and the severity of periodontal disease in AC and NC groups are summarized in Table 1. The NC group had more males than females and their mean age was slightly higher than the AC group. Generalized moderate chronic periodontitis cases made up the majority of AC and NC and there was only one current moderate smoker in each group.

Tooth loss at APT

The duration and number of teeth extracted during APT are shown in Table 2. During APT, RC lost 1.3 teeth/patient while IC lost 1.5 teeth/patient, with no significant difference between the two groups ($p = 0.50$). Multi-rooted teeth were lost at a higher frequency compared

with single-rooted teeth. For both the groups, the odds for the tooth type that was extracted during APT were about twofold for multi-rooted compared with single-rooted teeth. For the intergroup comparison, there was no significant difference regarding the type of teeth (single- *versus* multi-rooted) extracted during APT ($p = 0.61$). As a whole, AC lost 1.3 teeth/patient during APT.

The mean duration of APT was 3.4 months for the NC, 1.2 months longer than that for AC. Before the start of APT, a total of 973 teeth were present, with a mean of 25.0 teeth/patient (SD: 5.4, range 13–32 teeth), with no significant differences compared with AC ($p = 0.16$), RC ($p = 0.17$) and IC ($p = 0.33$). During APT, the NC lost 1.1 teeth/patient and the teeth extracted represented 4.2% of the total number of teeth present at the initial visit. Multi-rooted teeth were almost twice likely to be extracted compared with single-rooted teeth.

Reasons for tooth loss at APT

The main reason for extractions in RC was due to periodontal reasons (62.7%) and an additional 12.3% were due to periodontal–endodontic reasons. The distribution of teeth according to the reasons for extraction for RC during APT is shown in Appendix S1. For IC, similarly, the extractions were mainly due to periodontal reasons (48.1%) and an additional 15.4% were due to periodontal–endodontic reasons. For teeth extracted due to purely periodontal reasons, 68% were multi-rooted and 32% were single-rooted. Similar to RC, multi-rooted teeth were more frequently extracted due to periodontal reasons compared with single-rooted teeth, with odds of 1.5–2.0 (data not shown).

The extractions in NC were mainly due to periodontal reasons (41.5%) and another 7.3% were due to periodontal–endodontic reasons. In the group of teeth extracted due to purely periodontal reasons, 52.9% were multi-rooted and 47.1% were single-rooted (data not shown).

Tooth loss during PM for compliers

The mean duration of PM for AC was 10.7 years (range 7.0–20.4 years). RC and IC commenced PM with a mean of 24.7 and 24.6 teeth/patient, respectively, with no difference between both the groups ($p = 0.91$). The duration, frequency and number of teeth extracted during PM are shown in Table 3. RC lost 228 teeth with an incidence of

Table 1. Patient characteristics

	Regular compliers	Irregular compliers	All compliers*	Non-compliers
No. of patients	239	34	273	39
Sex				
Female	142 (59.4%)	25 (73.5%)	167 (61.2%)	16 (41.0%)
Male	97 (40.6%)	9 (26.5%)	106 (38.8%)	23 (59.0%)
Mean age/years	44.5	46.6	44.7	49.3
Range	19–80	25–65	19–80	26–70
Diabetics (type II)	17 (7.1%)	4 (11.8%)	21 (7.7%)	6 (15.4%)
Smokers				
Current smoker	1	0	1	1
Ex-smoker	1	0	1	0
Mild periodontitis	53 (22.2%)	7 (20.6%)	60 (22.0%)	4 (10.3%)
Moderate periodontitis	160 (66.9%)	24 (70.6%)	184 (67.4%)	27 (69.2%)
Severe periodontitis	26 (10.9%)	3 (8.8%)	29 (10.6%)	8 (20.5%)

*Regular and irregular compliers combined.

Table 2. Duration, number of teeth present and lost during active periodontal therapy (APT)

	Regular compliers ($n = 239$)	Irregular compliers ($n = 34$)	All compliers* ($n = 273$)	Non-compliers ($n = 39$)
Duration of APT (months)	2.2	2.3	2.2	3.4
Teeth at start of APT				
Total	6199	887	7086	973
Range	11–32	16–32	11–32	13–32
Mean/patient (SD)	25.9 (3.9)	26.1 (4.4)	26.0 (4.0)	25.0 (5.4)
Teeth at the end of APT				
Total	5891	835	6726	932
Range	11–32	16–31	11–32	7–32
Mean/patient (SD)	24.7 (4.3)	24.6 (4.1)	24.6 (4.3)	23.9 (6.3)
Teeth lost during APT (all reasons)				
Total	308 (5.0%)	52 (5.9%)	360 (5.1%)	41 (4.2%)
Range	0–11	0–9	0–11	0–13
Mean/patient (SD)	1.3 (1.9)	1.5 (2.2)	1.3 (2.0)	1.1 (2.4)
Single-rooted teeth	111 (36%)	17 (33%)	128 (36%)	15 (36.6%)
Multi-rooted teeth	197 (64%)	35 (67%)	232 (64%)	26 (63.4%)

*Regular and irregular compliers combined.

Table 3. Duration, number of teeth present and lost during periodontal maintenance (PM)/discontinuation of PM

	Regular compliers	Irregular compliers	All compliers	Non-compliers
Patients	239	34	273	39
Duration of PM/years (range)	10.9 (7.0–20.4)	9.4 (7.2–16.6)	10.7 (7.0–20.4)	9.6 (7.7–11.6)
Teeth at start of PM*				
Total	5891	835	6726	932
Range	11–32	16–31	11–32	7–32
Mean/patient (SD)	24.7 (4.3)	24.6 (4.1)	24.6 (4.3)	23.9 (6.3)
Teeth at end of PM*				
Total	5663	810	6473	825
Range	9–32	11–31	9–32	0–32
Mean/patient (SD)	23.7 (4.5)	23.8 (4.8)	23.7 (4.6)	21.2 (8)
Teeth lost during PM*(all reasons)				
Total	228 (3.9%)	25 (3.0%)	253 (3.8%)	107 (11.5%)
Range	0–8	0–7	0–8	0–17
Mean/patient (SD)	1.0 (1.4)	0.7 (1.4)	0.9 (1.4)	2.7 (4.4)†
Tooth loss/patient/year	0.09	0.08	0.09	0.29†
Single-rooted teeth	71 (31.1%)	17 (68%)	88 (34.8%)	65 (60.7%)
Multi-rooted teeth	157 (68.9%)	8 (32%)	165 (65.2%)	42 (39.3%)

*Period of discontinuation for non-compliers.
†Statistically significant between groups.

Table 4. Teeth lost due to periodontitis during periodontal maintenance (PM)/discontinuation of PM

	Regular compliers	Irregular compliers	All compliers	Non-compliers
Teeth lost due to perio only	73 (32.0%)	3 (12.0%)	76 (30.0%)	81 (75.7%)
Teeth lost due to perio–endo lesions	23 (10.1%)	1 (4.0%)	24 (9.5%)	3 (2.8%)
Teeth lost due to periodontitis (perio+perio – endo)				
Total	96 (42.1%)	4 (16.0%)	100 (39.5%)	84 (78.5%)
Range	0–4	0–2	0–4	0–13
Mean/patient (SD)	0.40 (0.82)	0.12 (0.41)	0.37 (0.78)	2.15 (3.55)
Tooth loss/patient/year	0.04	0.01	0.03	0.22*
Single-rooted teeth	17 (17.7%)	3 (75.0%)	20 (20.0%)	49 (58.3%)
Multi-rooted teeth	79 (82.3%)	1 (25.0%)	80 (80.0%)	35 (41.7%)

*Statistically significant between groups.

0.09 teeth/patient/year. A higher frequency of extraction was noted for multi-rooted (68.9%) compared with single-rooted teeth (31.1%). IC lost 25 teeth with an incidence of 0.08 teeth/patient/year, which was not significantly different from RC ($p = 0.65$). Of the teeth that were lost, 68% were single rooted while 32% were multi-rooted. RC were more likely to lose a multi-rooted tooth during PM ($p = 0.001$) with an odds ratio of 4.7 (95% CI: 1.9–11.4) compared with IC. Extractions were carried out in 111 RC and 13 IC during PM. AC had an incidence of 0.09 teeth/patient/year, with a higher frequency of extraction of multi-rooted teeth.

Reasons for tooth loss during PM for compliers

The majority of the extractions in RC were due to periodontal reasons (32.0%) and an additional 10.1% were due to periodontal–endodontic reasons. The distribution of teeth according to the reasons for extraction during PM is shown in Appendix S2. For teeth that were extracted due to purely periodontal reasons, 79.5% were multi-rooted and 20.5% were single-rooted (data not shown).

For IC, the extractions were mainly due to prosthodontic reasons (44.0%). Only 12.0% were extracted due to periodontal reasons and 4.0% due to periodontal–endodontic reasons.

Extent of tooth loss due to periodontitis in compliers

It is prudent to evaluate the extent of tooth loss due to periodontitis even after successful APT. Tooth loss due to periodontitis would include periodontal as well as periodontal–endodontic reasons. RC lost 96 teeth due to periodontitis, with an incidence of 0.04 teeth/patient/year. The extent of teeth lost due to periodontitis during PM is shown in Table 4. Of the teeth that were lost, a much higher frequency was obtained for multi-rooted teeth compared with single-rooted teeth. IC lost 0.01 teeth/patient/year, with no significant difference between both the groups ($p = 0.55$). As a whole, AC lost 0.03 teeth/patient/year due to periodontitis.

Tooth loss during the discontinuation of PM in NC

After the completion of APT, this group of patients chose not to follow up with PM. These patients were invited for a recall and a clinical assessment of the incidence and reasons of tooth loss was performed. The main reasons for the discontinuation of PM were lack of time (14 patients, 35.9%) and patients did not perceive the need for treatment (16 patients, 41.0%). The rest discontinued due to fear (seven patients, 18.0%) and cost (two patients, 5.1%).

The mean period of discontinuation of PM was 9.6 years (range 7.7–11.6 years). The duration and number of teeth lost during the discontinuation of PM for NC are compared with compliers in Table 3. During the discontinuation of PM, a total of 107 teeth were lost (2.7 teeth/patient), and this was statistically significant compared with RC ($p < 0.001$), IC ($p = 0.01$) and AC ($p < 0.001$). The incidence of tooth loss was 0.29 teeth/patient/year, which was statistically higher compared with RC ($p < 0.002$), IC ($p = 0.02$) and AC ($p < 0.001$).

Of the teeth that were lost, 60.7% were single-rooted, while 39.3% were multi-rooted teeth. Comparing these results, AC were more likely to lose a multi-rooted tooth during PM ($p < 0.001$) compared with NC losing a multi-rooted tooth during the discontinuation of PM, with an odds ratio of 2.9 (95% CI: 1.8–4.6).

Reasons for tooth loss during the discontinuation of PM in NC

The tooth lost during the period of discontinuation was mainly due to periodontal reasons (75.7%) and another 2.8% due to periodontal–endodontic reasons. The distribution of teeth according to the reasons for extraction is shown in Appendix S2.

Tooth loss due to periodontitis during the discontinuation of PM in NC

During the discontinuation of PM, 84 teeth were lost due to periodontitis (periodontal and periodontal–endodontic reasons), leading to a mean loss of 2.15 teeth/patient. A higher frequency was observed for single-rooted teeth (58.3%) compared with multi-rooted teeth (41.7%). The extent of tooth loss due to periodontitis during the period of discontinuation of PM is shown in Table 4. The tooth loss due to periodontitis was 0.22 teeth/patient/year, which was significantly higher than that of RC ($p < 0.001$), IC ($p = 0.01$) and AC ($p < 0.001$).

Regression analysis

The data for RC and IC were combined and analysed as a whole. To correct for confounding factors, a logistic multiple regression model was constructed to determine the prediction of tooth loss during PM and discontinuation of PM. The following independent patient-related variables were included: age, gender, diabetes, the initial periodontal diagnosis, number of teeth present at the start of the PM visit, undergone periodontal surgery as part of therapy and compliance with the recommended PM attendance. Smoking habit was not entered into the model as there was only one current moderate smoker and one ex-smoker in the AC group. Within this analysis, patients <60 years of age were categorized as young, the initial periodontal diagnosis was dichotomized into severe periodontitis or mild/moderate periodontitis and compliance during

Table 5. Logistic regression analysis: Predictors of tooth loss during periodontal maintenance (PM) (regular and irregular compliers)

Variable	Significance	Odds ratio	Confidence interval
No. teeth at the start of PM	0.64	0.8	0.93–1.05
Health (diabetics *versus* non-diabetics)	0.31	2.1	0.63–4.30
Therapy (surgical *versus* non-surgical)	0.64	1.0	0.68–1.86
Periodontal diagnosis (severe *versus* mild/moderate)	0.96	0.8	0.43–2.22
Gender (male *versus* females)	0.64	0.9	0.53–1.47
Compliance with SPT (regular *versus* irregular)	0.23	1.4	0.75–3.42
Age ($\geqslant$60)	0.015	2.1	1.14–3.40

Table 6. Logistic regression analysis: Predictors of tooth loss during the discontinuation of periodontal maintenance (PM) (non-compliers)

Variable	Significance	Odds ratio	Confidence interval
Periodontal diagnosis (severe *versus* mild/moderate)	0.073	7.5	0.83–73.75
Gender (male *versus* females)	0.53	0.7	0.16–2.61
Age ($\geqslant$60)	0.77	0.9	0.19–3.44
Health (diabetics *versus* non-diabetics)	0.53	1.7	0.25–14.65

PM was dichotomized into regular or irregular compliance.

The results of the logistic regression analysis are shown in Table 5. In this model, the age of $\geqslant$60 was found to be a highly significant predictor of tooth loss for the compliers during PM ($p = 0.015$), with an adjusted odds ratio of 2.1 (95% CI: 1.14–3.40). The rest of the variables failed to reach significance as predictors of tooth loss during PM.

For NC, the following patient-related variables were analysed: age, gender, diabetes and initial periodontal diagnosis. Smoking habit was not entered into the model as there was only one current moderate smoker in the recruited sample. The results of the regression analysis are shown in Table 6. There were no significant predictors for tooth loss during the discontinuation of PM.

Discussion

Patients

In this study, AC consisted of 87.5% RC, which was higher than that in most other studies: 35.8% (Wilson et al. 1987), 35.6% (Miyamoto et al. 2006) and 53% (Eickholz et al. 2008). However, these studies adopted various definitions for compliance. To date, it has been recognized that the method of classifying and quantifying a patient's compliance is an inherent limitation of any study of compliance (Miyamoto et al. 2006).

There are very few studies in the literature showing the rate of tooth loss in populations who had received periodontal treatment but were not maintained (Becker et al. 1984a, Leung et al. 2006). There are even fewer studies comparing the incidence of tooth loss in patients who received PM with patients who were not maintained after APT. Only one group of researchers investigated tooth loss in their group of patients who were periodontally treated but not maintained, and another group that was treated and maintained (Becker et al. 1984a, b).

Tooth loss during APT

Tooth loss has been considered the most relevant parameter to evaluate the efficacy of dental treatment: a true clinical end point (Hujoel et al. 1999, Tonetti et al. 2000, Hujoel 2004). Several studies have reported tooth loss during APT that ranged from 2.3% to 7.5% (Appendix S3). The present study noted 4.2–5.9% tooth loss, with no significant difference between the groups (RC, IC, NC) ($p = 0.44$). This indicated that patients from all groups were receptive to the initial periodontal treatment plan. The findings from the present study were comparable to studies by Tonetti et al. (2000), Checchi et al. (2002) and König et al. (2002) but had much lower values than those of Carnevale et al. (2007b) and Matuliene et al. (2008). The decision to extract a tooth could be influenced by many factors, which included individual dentist's treatment philosophy and individual patient's attitude (Zaher et al. 2005). Subjects from studies of Carnevale et al. (2007b) and Matuliene et al. (2008) included a higher proportion of severe periodontitis (40.8% and 89%, respectively) as compared with the present study of 10.6%, thus possibly leading to more teeth being indicated for extractions during APT.

Reasons for tooth loss during APT

The tooth loss for RC was mainly due to periodontal and periodontal–endodontic reasons. For IC, similarly, tooth loss was due to periodontal reasons. This finding closely approximated those reported in one of the earlier studies (Tonetti et al. 1998, 2000), where periodontal problems were responsible for 63% of extractions, while a combination of periodontal problems with caries, endodontic or technical problems accounted for another 14% of extractions.

A multi-rooted tooth was almost twice as likely to be extracted for RC and IC. Checchi et al. (2002) found that multi-rooted teeth were generally lost more frequently than single-rooted teeth (4% *versus* 1%) during APT and PM. When teeth lost due to periodontal reasons were examined, the same finding was reported, with multi-rooted teeth extracted more frequently. McLeod et al. (1997) obtained similar findings and attributed it to hygienic and therapeutic difficulties because of root morphology and the distal positioning of multi-rooted teeth in dental arches.

Tooth loss during PM

Studies that analysed tooth loss both during APT and PM reported extraction rates ranging from 0.9% to 7.8% (Appendix S3). In this study, 3.8% of teeth were extracted, which was similar to those reported in other studies: 4.2% (Tonetti et al. 2000) and 3.1% (König et al. 2002). Some studies had reported a higher percentage of tooth loss ranging from 6.7% to 7.8% during PM (McLeod et al. 1997, Faggion et al. 2007, Eickholz et al. 2008) and this could be due to a lower initial extraction rate during APT (2.3–3.6%) as compared with the present study of 5.1%. Carnevale et al. (2007b) reported a very low incidence of 0.9% tooth loss during PM, which might be due to an initial high extraction rate of 7.5% during APT. By extracting more questionable teeth during active treatment, the risk of tooth loss during

PM is likely to be reduced (Tonetti et al. 2000, Eickholz et al. 2008). However, the recall intervals varied between the studies and one must be cautious while interpreting the data.

The present study observed that compliers had a mean tooth loss of 0.9 teeth/patient, which was in agreement with the recent systematic review that reported 0.7–3.0 teeth lost per patient for university-based trials (Chambrone et al. 2010). This shows that the provision of a PM programme in our local population is effective in minimizing tooth loss and is comparable to studies from other geographical locations.

The compliers had a higher incidence of loss of multi-rooted teeth (65.2%) compared with single-rooted teeth (34.8%), similar to that reported by Checchi et al. (2002) as discussed previously. Pretzl et al. (2008) also reported a worse prognosis of multi-rooted teeth even without furcation involvement, compared with single-rooted teeth. However, furcation involvement further increased the risk for tooth loss of multi-rooted teeth. Such tooth-related parameters aid in the treatment planning of individual teeth (Persson 2005).

Reasons for tooth loss during PM

The majority of extractions in RC were due to periodontal and periodontal–endodontic reasons. This high incidence could be due to the fact that some patients might have declined the indicated extractions during APT and these teeth were subsequently lost during the monitoring period of 10.7 years. Maintenance of severely compromised teeth may increase the risk of tooth loss during PM (Tonetti et al. 2000).

Tooth loss due to periodontitis for AC was similar to that found in several previous studies (König et al. 2002, Fardal et al. 2004, Chambrone & Chambrone 2006, Carnevale et al. 2007b), but less than some of the earlier studies, which reported a range of 0.07–0.14 (Hirschfeld & Wasserman 1978, McFall 1982, Wood et al. 1989, McLeod et al. 1997, Tonetti et al. 2000, Checchi et al. 2002). Subjects from the latter studies were predominantly patients with advanced periodontitis and this could explain the higher annual tooth loss due to periodontitis compared with the current study. This study found a mean tooth loss due to periodontitis of 0.37 teeth/patient, which was in agreement with the recent systematic review that reported a range of 0.3–2.6 teeth/patient (Chambrone et al. 2010).

Tooth loss during the discontinuation of PM

Becker et al. (1984a) examined a group of 44 patients 5.25 years after they had dropped out after the completion of APT. These patients experienced a loss of 0.29 teeth/patient/year (0.22 teeth/patient/year after adjusting for teeth with a hopeless prognosis), which was similar to our observation (0.29 teeth/patient/year). However, the causes of tooth loss were not limited to periodontal reasons in that study.

The study by Leung et al. (2006) recalled 97 patients who had previously undergone supervised periodontal therapy by final-year undergraduate dental students a mean of 8.9 years ago. Two hundred and fifty-six teeth (10.2%) had been lost during the discontinuation period and this amounted to a loss of 0.25 teeth/patient/year. Our findings closely approximated the results from these studies (Becker et al. 1984a, Leung et al. 2006). Together with these limited studies, our results support the concept that periodontal treatment without maintenance is of questionable value in terms of maintaining periodontal health and teeth.

When compared with previous long-term retrospective studies (Hirschfeld & Wasserman 1978, McFall 1982, Wood et al. 1989, McLeod et al. 1997, Tonetti et al. 2000, Checchi et al. 2002, König et al. 2002, Faggion et al. 2007), the current data revealed that the completion of APT without PM resulted in twice the number of tooth extractions. However, when our results were compared with studies that investigated susceptible patients who did not receive any periodontal treatment (Löe et al. 1978, Becker et al. 1979, Buckley & Crowley 1984, Harris 2003), the incidence of tooth loss was about the same, if not marginally lower. This indicated that rendering periodontal treatment without subsequent maintenance may provide limited benefits with regards to tooth retention.

The incidences of overall tooth loss and tooth loss due to periodontitis for the NC were significantly higher than that of the RC, IC and AC ($p < 0.05$). Receiving periodontal treatment without subsequent maintenance will predispose the patient to further tooth loss, which is in agreement with previously reported studies (Kocher et al. 2000, Checchi et al. 2002). This further strengthens the importance and benefit of a PM programme (Knowles et al. 1979, Pihlström et al. 1983, Lindhe & Nyman 1984, Ramfjord et al. 1987, Kaldahl et al. 1996, Axelsson et al. 2004).

Prognostic factors

Age of $\geqslant 60$ was found to be a highly significant predictor of tooth loss during PM in AC. Older age (>60 years old) was also observed to be a predictor of tooth loss due to progressive periodontitis [Fardal et al. 2004 (OR = 4.0), Chambrone & Chambrone. 2006 (OR = 7.1)]. Patients of an older age group (Grossi et al. 1994, 1995) tended to have more severe periodontal disease in terms of attachment loss or bone height. The current view sees the greater periodontal destruction in the elderly as reflecting lifetime disease accumulation rather than an age-specific condition (Burt 2005).

The current study failed to identify gender and initial periodontal diagnosis as a significant predictor of tooth loss during PM. It was reported that male gender was associated with more severe periodontal disease (Grossi et al. 1995) and was a significant predictor of tooth loss (OR = 2.8) (Fardal et al. 2004). This could be attributed to males exhibiting poorer oral hygiene, rather than any biological basis. Initial diagnosis was identified as having a statistically significant influence on tooth loss (Eickholz et al. 2008). Patients with aggressive and generalized severe chronic periodontitis had a twofold risk for tooth loss compared with those with moderate periodontitis (Eickholz et al. 2008). These observations are consistent with the notion that previous periodontal destruction may represent a clinical estimation of the patient's susceptibility to periodontal disease (Papapanou & Wennstrom 1990). In the present study, the population consisted of only 10.6% with severe periodontitis and most of these patients attended PM regularly (89.7%). This may explain the failure to identify the initial periodontal diagnosis as a predictor for tooth loss.

It has been shown that patients complying erratically with maintenance therapy after periodontal treatment were at 3.2-fold (Eickholz et al. 2008) to 5.6-fold (Checchi et al. 2002) greater risk of tooth loss than regularly compliant patients. Within the limitations, compliance during PM was not a significant predictor of tooth loss for the present study. IC made

up only 12.5% of the compliers' population (unlike the higher number of IC in samples from Checchi et al. 2002, Eickholz et al. 2008) and therefore, the sample size may be too small to pick up significant differences.

For NC, analysis of the four patient-related variables (age, gender, diabetes, initial periodontal diagnosis) failed to explain tooth loss during the discontinuation of PM sufficiently, indicating that these variables had a minor impact on treatment outcome. Other patient-related factors, psychosocial status and genetic susceptibility might also be possible confounding factors.

To our knowledge, there is only one study that has performed a regression analysis to analyse variables associated with tooth loss during discontinuation in patients who were not maintained on PM (Leung et al. 2006). The authors found that age, years elapsed since the end of previous periodontal treatment, smoking – pack-years and self-reported daily oral hygiene practice duration were found to be related to both further total tooth loss and further tooth loss because of periodontal reasons.

Our study only managed to recruit a single NC patient who is a current smoker and hence, it was not feasible for analysis of smoking habit in the model. In addition, we found it difficult to obtain accurate information on self-reported daily oral hygiene practice for NC; hence, this variable was not analysed in our study. The regression analyses did not pick up age $\geqslant 60$ years old as a significant variable and this could be due to the small sample of patients who were $\geqslant 60$ years old (eight out of 39 patients).

Study limitations

This study was conducted at an institution with several periodontists. There will be inherent differences in the measurement, classification of periodontal parameters and treatment plan among different clinicians. To address variations in initial periodontal diagnoses, the principal investigator, who was not involved in the clinical treatment of these patients, retrospectively re-assigned the initial periodontal diagnosis according to Armitage (1999), using the clinical charts and radiographs.

The retrospective study consisted of AC who are motivated and these patients are still undergoing PM. The proportion of RC is very much higher than IC. In addition, at the initial visit, the majority of patients in AC and NC had generalized moderate periodontitis, followed by mild and severe periodontitis in AC and severe and mild periodontitis in NC.

The responder rate of the NC to the clinical recall exam was very low ($\sim$19%). For NC, the reasons for extraction were obtained through chair-side interview and self-reporting by the patient, unlike AC, where information was obtained from the patients' clinical notes. Thus, there might be inherent inaccuracies in the collection of information as these patients might not remember the actual reasons for tooth loss, especially as they had discontinued PM 7 years or more after the initiation of periodontal treatment.

The patients in this study were recruited from one clinical facility and the results reported here should not be generalized to patients attending treatment at private offices or periodontal patients from another geographical location.

Conclusions

This study showed that chronic periodontitis can be treated successfully. Local patients, who were followed up on PM after the treatment of periodontitis, had a low incidence of tooth loss (one tooth in 10 years), regardless of the level of compliance. Tooth loss still occurred in patients who were on regular PM, albeit at a low rate. Periodontitis remained the main reason for tooth loss during PM; this indicated that periodontitis-susceptible patients were still at a risk of further progression of periodontitis even after initial successful periodontal treatment. Periodontally involved multi-rooted teeth had a worse prognosis compared with single-rooted teeth.

To illustrate the true effectiveness of PM, a comparison was made with another group of patients who discontinued treatment after APT (NC). The mean tooth loss and overall tooth loss for NC (2.7 teeth/patient, 0.29 teeth/patient/year, respectively) was about threefold higher than AC (0.9 teeth/patient, 0.09 teeth/patient/year, respectively). The difference was statistically significant ($p < 0.001$). Similarly, the tooth loss was mainly due to periodontal reasons. The NC had about a sevenfold higher incidence of tooth loss due to periodontitis compared with AC (0.22 *versus* 0.03 teeth/patient/year), which was statistically significant ($p < 0.001$). The high incidence of tooth loss during discontinuation might be interpreted as further progression of periodontitis in the absence of PM. This further highlighted the importance of instituting regular PM after the completion of APT.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Reasons for tooth loss during APT.
Appendix S2. Reasons for tooth loss during PM/discontinuation of PM.
Appendix S3. Studies that examined tooth loss both during APT and PM.

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Clinical Relevance

Scientific rationale for the study: Very few studies have analysed tooth loss (particularly due to periodontitis) both during APT and PM in the same group of patients as well as in patients who had completed APT but did not participate in PM. More evidence on the impact of patients' compliance during PM on tooth survival is needed.

Principal findings: In this group of patients maintained for an average of 10.7 years, they lost 5.1% of the teeth during APT and 3.8% of the teeth during PM, with no significant difference between the RC and the IC. The group experienced tooth loss of 0.09 teeth/patient/year, with the age of $\geqslant 60$ being a significant predictor of tooth loss during PM. For patients who discontinued PM for an average of 9.6 years, they lost 4.2% of the teeth during APT and 11.5% of the teeth during the absence of PM. The group experienced an overall tooth loss of 0.29 teeth/patient/year, which was about threefold higher than the compliers. NC had about a sevenfold higher annual incidence of tooth loss due to periodontitis compared with AC (0.03 *versus* 0.22 teeth/patient/year).

Practical implications: In this study, subjects on a PM programme had a low incidence of annual tooth loss regardless of the level of compliance. Patients who opted out of periodontal therapy after APT lost significantly more teeth compared with patients who were on regular PM. This further indicated the importance of PM after periodontal disease had been controlled. PM should remain an essential component of periodontal care in terms of improving periodontal health as well as reducing the incidence of tooth loss in a periodontally involved dentition.