J Clin Periodontol 2010; 37: 675–684 doi: 10.1111/j.1600-051X.2010.01587.x

Journal of Clinical Periodontology

Predictors of tooth loss during long-term periodontal maintenance: a systematic review of observational studies

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Chambrone L, Chambrone D, Lima LA, Chambrone LA. Predictors of tooth loss during long-term periodontal maintenance: a systematic review of observational studies. J Clin Periodontol 2010; 37: 675–684. doi: 10.1111/j.1600-051X.2010.01587.x

Abstract

Objective: To systematically assess the factors influencing tooth loss during long-term periodontal maintenance (PM).

Methods: CENTRAL, MEDLINE and EMBASE were searched up to and including September 2009. Studies limited to patients with periodontitis who underwent periodontal therapy and followed a maintenance care programme for the at least 5 years were eligible for inclusion in this review. Studies were considered for inclusion if they reported data on tooth loss during PM.

Results: The search strategy identified 527 potentially eligible articles, of which 13 retrospective case series were included in this review. The risk of bias assessment evaluated by the Newcastle–Ottawa scale showed that eight studies were considered of medium methodological quality and five of low methodological quality. Of 41,404 teeth present after active periodontal treatment, 3919 were lost during PM. The percentages of tooth loss due to periodontal reasons and of patients who did not experience tooth loss varied from 1.5% to 9.8% and 36.0% to 88.5%. Studies' individual outcomes showed that different patient-related factors (i.e. age and smoking) and tooth-related factors (tooth type and location, and the initial tooth prognosis) were associated with tooth loss during PM.

Conclusions: The considerable heterogeneity found among studies did not allow definitive conclusions. Age, smoking and initial tooth prognosis were found to be associated with tooth loss during PM. Overall, patients must be instructed to follow periodic PM and quit smoking (smokers). Prospective cohort studies are required to confirm the possible predictors of tooth loss due to periodontal reasons. The allocation of patients into subgroups according to the type of periodontitis and smoking frequency will allow more accurate evaluations.

Key words: long-term maintenance; periodontal disease; supportive periodontal therapy; systematic review; tooth loss

Accepted for publication 5 April 2010

Periodontal maintenance (PM) is the group of procedures performed at selected intervals to assist the periodontal patient in maintaining oral health (AAP 2001). Formerly referred to as recall maintenance, preventive maintenance or supportive periodontal therapy, this periodic assessment is established following the initial active periodontal therapy (APT) and it includes an update of the medical and dental histories, extra-oral and intra-oral soft tissue examination, dental examination, periodontal evaluation, radiographic review, removal of the bacterial flora deposits from crevicular and pocket areas, scaling and root planning where indicated, polishing of the teeth and a review of the patient's plaque control efficacy (AAP 1998, 2001). These procedures aim to prevent the recurrence and progression of periodontal disease and to prevent or reduce the incidence of tooth loss (AAP 1998).

Reports from several studies showed the effectiveness of periodontal treatment and long-term PM in maintaining perio-

Conflict of interest and source of funding statement

Conflict of interest: the authors report no conflicts of interest related to this study.
Source of support: none.

dontal health and in preventing tooth loss in patients with periodontitis (Oliver 1969, Ross et al. 1971, Hirschfeld & Wasserman 1978, McFall 1982, Lindhe & Nyman 1984, Goldman et al. 1986, Wood et al. 1989, Tonetti et al. 1998, 2000, Checchi et al. 2002, König et al. 2002, Axelsson et al. 2004, Fardal et al. 2004, Dannewitz et al. 2006, 2009, Chambrone & Chambrone 2006, Carnevale et al. 2007b, Faggion et al. 2007, Eickholz et al. 2008, Lorentz et al. 2009, Lulic et al. 2009, Pretzl et al. 2009). These studies unanimously found low rates of tooth loss.

On the other hand, the predictability of such maintenance procedures may be associated with diverse conditions, especially when a patient is exposed to one or more risk factors known to influence host response (Fardal et al. 2004, Chambrone & Chambrone 2006). For instance, there is evidence clear that smoking may negatively affect the results achieved through periodontal therapy (Kaldahl et al. 1996, Kinane & Chestnutt 2000, Stavropoulos et al. 2004, Johnson & Guthmiller 2007, Chambrone et al. 2008, 2009a, c, Wan et al. 2009). Likewise, other local, systemic or environmental factors might contribute to the amount of tooth loss during PM (Heitz-Mayfield 2005). However, the aleatory comparison of studies may not be considered efficient in drawing precise conclusions and can lead to misleading interpretations. To date, to our knowledge, there is no compilation of evidence-based information documenting the effect of patient- and tooth-related factors contributing to tooth loss during PM.

Therefore, the objective of this review was to systematically assess the predictors of tooth loss among patients who underwent periodontal therapy and long-term PM, by answering the following question: ''What is the effect of local and systemic risk factors on tooth loss during long-term periodontal maintenance?''

Methods

Criteria for considering studies for this review

Type of studies, type of intervention and inclusion criteria

As the research question is one of prognosis and owing to the impossibility of randomizing risk factors such as age or smoking, the most appropriate research design to answer this issue is a systematic review of observational studies. Therefore, longitudinal prospective/retrospective studies [cohort studies, case–control studies and case series (CSs)] limited to patients with periodontitis who underwent APT and followed a maintenance care programme for at least 5 years were eligible for inclusion in this review. Studies were considered for inclusion if they involved the following: (1) data on tooth loss, i.e. number, percentage or mean number of teeth lost during PM; (2) statistical analysis performed to investigate the association between different independent variables (e.g. age, gender, smoking) with tooth loss, or at least the raw data from these variables; (3) absence of patients with a history of refractory periodontitis or AIDS; and (4) absence of patients who did not return to PM. In cases in which a trial reported data from both compliant and non-compliant patients, yet the study's results included tooth loss from each group of subjects in separate, the study was considered for inclusion as well.

Outcome measure

Tooth loss during PM.

Search strategy

For the identification of studies included or considered for this review, detailed search strategies were developed for each database searched based on the search strategy presented below for searching the Medical Literature Analysis and Retrieval System Online (MEDLINE). The MEDLINE (via PubMed), EMBASE and Cochrane Central Register of Controlled Trials (CENTRAL) databases were searched up to and including September 2009. Databases were searched to include papers and abstracts published in all languages. MesH terms, key words and other free terms were used for searching, and Boolean operators (OR, AND) were used to combine searches. The search strategy applied was:

((((periodontal maintenance) OR (supportive periodontal therapy)) OR (maintenance care)) OR (long-term maintenance)) OR (long-term effects)
((specialist periodontal practice) OR (treatment outcome)) OR (longitudinal study)
(#1) AND (#2)
(tooth loss) OR (tooth mortality)
(periodontitis) OR (periodontal disease)
(#4) AND (#5)
(#3) AND (#6)

Unpublished data were sought by searching a database listing unpublished studies (OpenSIGLE). In addition, reference lists of any potential studies were examined (i.e. hand searching) in an attempt to identify any other papers. The authors of included studies were contacted when necessary for clarification of data or to obtain missing data.

Assessment of validity, data extraction and methodological quality

Two independent reviewers (L. C. and D. C.) screened the titles, abstracts and full texts of the articles identified by searching. Disagreement between the reviewers was resolved by discussion and consensus. Data were excluded if agreement could not be reached. The agreement between the review authors for study inclusion was assessed using the κ statistic. Data on the following issues were extracted and recorded: (1) citation, publication status and year of publication; (2) location of the trial; (3) study design (cohort study or CS); (4) characteristics of the participants; (5) characteristics of the interventions; (6) outcome measures; and (7) methodological quality of the trials.

The methodological quality of the observational studies was assessed using the Newcastle–Ottawa scale (NOS-scale) (Wells et al. 2001) focusing on the following points (Appendix S1):

- Selection of study groups (i.e. patients who experienced or not tooth loss): (1) representativeness of the patients who experienced tooth loss during PM; (2) selection of the patients who did not experience tooth loss during PM; (3) ascertainment of tooth loss; and (4) demonstration that the number of teeth present after APT was reported in the study.
- Comparability of patients: comparability of patients on the basis of the study design or analysis.
- Outcome of interest (i.e. tooth loss): (1) assessment of tooth loss; (2) data from the number of teeth lost due to periodontal reasons after reported in the study; and (3) adequacy of follow-up of the patients.
- Statistical analysis: (1) validity of statistical analysis and (2) unit of analysis.

If all criteria of methodological quality were fulfilled within the domains, points (''stars'') were assigned to the respective study. The NOS scale was adapted for the purpose of this review

and each study included could receive a maximum of 11 points. Studies with 9–11 points were arbitrarily considered as being of high, with 6–8 points of medium and with <6 points as being of low methodological quality.

Data synthesis

Data were pooled into evidence tables and grouped according to the type of study. A descriptive summary was performed to determine the quantity of data, checking further for study variations in terms of the study characteristics and results. This assisted in confirming the similarity of studies and the suitability of reporting studies' individual comparisons in subgroups according to the type of predictor factor, i.e. patient- or tooth-related factors.

Results

Description of studies

Results of the Search

The search strategy identified 527 potentially eligible articles, of which 493 were excluded after the title and/or the abstract were reviewed [κ score for interreviewer agreement: 0.82, 95% confidence interval (CI): 0.70–0.93]. Subsequently, the full texts of the remaining articles considered potentially relevant were screened. Of these papers, 19 did not meet the inclusion criteria and were excluded (κ score for interreviewer agreement: 0.75, 95% CI: 0.58–0.88) (Fig. 1).

Included studies

Fifteen papers were included in this review regarding 13 retrospective CSs, and their main characteristics (i.e. methods, participants, intervention, outcomes, place of treatment and location) are depicted in Table 1. Two CSs had their data reported in two articles (McLeod et al. 1997, 1998, Eickholz et al. 2008, Pretzl et al. 2008); therefore, the papers were grouped under the one study name (i.e. McLeod et al. 1997, 1998, Eickholz et al. 2008, Pretzl et al. 2008). Overall, the majority of trials followed participants during a period of at least 10 years, and a total of 2147 patients were treated in the 13 CSs.

Tooth loss associated with patient- and tooth-related factors

Given the marked heterogeneity of the groups and procedures reported (i.e., study population, initial tooth diagnosis, treatment provided, maintenance interval and information on the putative factors that were tested to influence tooth loss during PM), the study characteristics were considered too variable to allow data to be combined for meta-analysis. The raw data from patient- and tooth-related factors were available for 10 surveys and these are depicted in Figs 2 and 3. Only five studies have reported raw data from patient-related factors, while eight described data from tooth-related factors (i.e. site-based). Of the 13 studies included, five did not report statistical comparisons of patient- or tooth-related risk factors (Hirschfeld & Wasserman 1978, Wood et al. 1989, McFall 1982, McLeod et al. 1998, Papantonopoulos 2004).

With respect to the remaining trials, studies' individual outcomes related to different predictors of tooth loss are described below:

Chambrone & Chambrone (2006) – The independent variables age >60

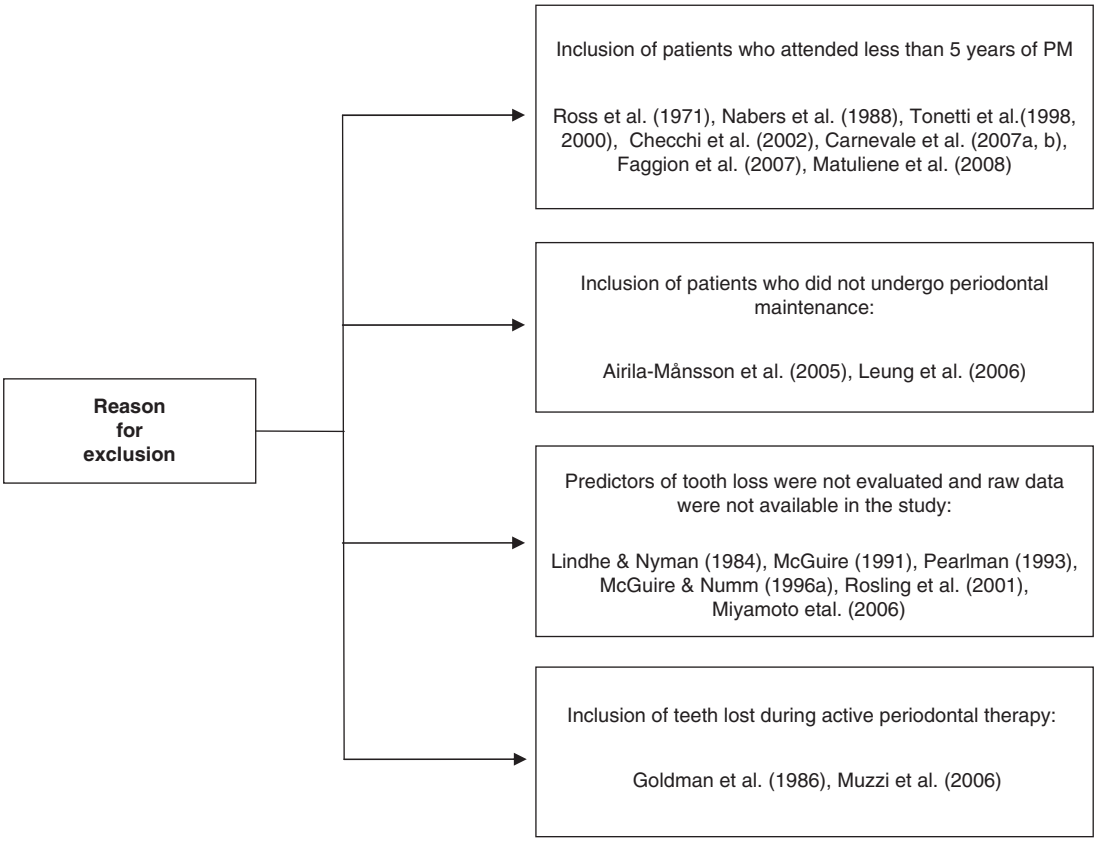

Fig. 1. Characteristics of the excluded studies.

Table 1. Characteristics of the included studies

Study	Methods	Participants	Maintenance interventions	Outcomes	Notes
Chambrone & Chambrone (2006)	CS, retrospective design, maintenance regime at a 6–12-month interval (mean 9.4 months), at least 10 years' duration (mean duration 17.4 years, range 10–36)	120 individuals, 73 females, 20 smokers, aged 20–72 at the time of initial therapy, with generalized chronic periodontitis Teeth present after APT = 2927 (mean 24.4 teeth/patient)	Oral hygiene measures, scaling, selective root planing, tooth polishing and topical fluorides	Total number of teeth lost during PM = 111 (0.9 teeth/patient) Teeth lost due to PR = 53 (0.4 teeth/patient) 77 patients lost no teeth (64.2%) 10 patients lost $\geq$ 4 teeth (8.3%) 8.3% of patients accounted for 51.3% of all teeth lost (57)	Practice-based (Brazil) Unpublished data were included following contact with author
Eickholz et al. (2008), Pretzl et al. (2008)	CS, retrospective design, maintenance regime at a 3–6-month interval, at least 10 years' duration (mean duration 10.5 years)	100 individuals, 59 females, 27 smokers, aged 15–67 at the time of initial therapy, with aggressive or generalized chronic periodontitis Teeth present after APT = 2301 (mean 23.0 teeth/patient)	Oral hygiene measures, professional tooth cleaning with hand instruments, selective root planing, tooth polishing and topical fluorides	Total number of teeth lost during PM = 155 (1.5 teeth/patient) Teeth lost due to PR = NR 49 patients lost no teeth (49.0%) 12 patients lost $\geq$ 4 teeth (12.0%) 12.0% of patients accounted for 58.7% of all teeth lost (91)	University-based (Germany) Unpublished data were included following contact with author
Fardal et al. (2004)	CS, retrospective design, maintenance regime between one and three times per year, at least 9 years' duration (mean duration 9.8 years, range 9–11)	100 individuals, 68 females, 26 smokers, aged 25–69 at the time of initial therapy, with generalized chronic periodontitis Teeth present after APT = 2436 (mean 24.3 teeth/patient)	Scaling, root planing and tooth polishing,	Total number of teeth lost during PM = NR Teeth lost due to PR = 36 (0.4 teeth/patient) 74 patients lost no teeth (74.4%) 3 patients lost four teeth (3.0% – no patient lost $>$4 teeth)	Practice-based (Norway)
Hirschfeld & Wasserman (1978)	CS, retrospective design, maintenance regime at a 4–6-month interval, at least 15 years' duration (mean duration 22.0 years, range 15–53)	600 individuals, 391 females, number of smokers NR, aged 12–73 at the time of initial therapy, with early to advanced periodontal disease Teeth present after APT = 15,666 (mean 26.2 teeth/patient)	Oral hygiene measures and deep scaling. Oral hygiene measures and occlusal adjustment as indicated	Total number of teeth lost during PM = 1312 (2.2 teeth/patient) Teeth lost due to PR = 1110 (1.8 teeth/patient) 300 patients lost no teeth (50.0%) 101 patients lost $\geq$ 4 teeth (16.8%) 16.0% of patients accounted for 69.2% of all teeth lost due periodontal reasons (768)	Practice-based (USA)
Jansson & Lagervall (2008)	CS, retrospective design, maintenance regime $\leq$ 6 month interval, at least 10 years' duration (mean duration 16.2 years, range10–24)	60 individuals, 77% of females, 83% of smokers, aged 27–55 at the time of initial therapy, with generalized chronic periodontitis Teeth present after APT = NR (mean 19.8 teeth/patient)	Oral hygiene instructions, scaling, root planing and tooth polishing	Total number of teeth lost during PM = NR (2.3 teeth/patient) Teeth lost due to PR = NR 24 patients lost $\geq$ 6 teeth (40.0%)	University-based (Sweden)
König et al. (2002)	CS, retrospective design, maintenance regime interval NR, at least 10 years' duration (mean duration 10.5 years, range 8–13)	146 individuals, 76 females, number of smokers NR, aged 23–72 at the time of initial therapy, with moderate to advanced periodontitis (predominantly generalized chronic periodontitis) Teeth present after APT = 3186 (mean 21.8 teeth/patient)	Professional tooth cleaning and selective subgingival debridement	Total number of teeth lost during PM = 99 (0.7 teeth/patient) Teeth lost due to PR = 48 (0.3 teeth/patient) 64 patients lost no teeth (45.0%) 05 patients lost $\geq$ 4 teeth (3.4%)	University-based (Germany)
Matthews et al. (2001)	CS, retrospective design, maintenance regime	335 individuals, 215 females, number of smokers NR, aged 16–77	NR	Total number of teeth lost during PM = 520 (1.5 teeth/patient)	University-based (Canada)

	interval NR, at least 10 years' duration (mean duration 16.1 years, range 10–38)	at the time of initial therapy, with chronic periodontitis Teeth present after APT = NR		Teeth lost due to PR = 322 (0.9 teeth/patient) 266 patients lost no teeth (79.4%) 29 patients lost ≥ 4 teeth (8.6%)	
McFall (1982)	CS, retrospective design, maintenance regime at a 3-, 4- or 5- month interval, at least 15 years' duration (mean duration 19.0 years, range 15–29)	100 individuals, 59 females, number of smokers NR, aged 08–71 at the time of initial therapy, with early to advanced attachment loss (type of periodontitis NR) Teeth present after APT = 2627 (mean 26.3 teeth/patient)	Scaling and tooth polishing Surgical interventions were performed when pocket depth increased	Total number of teeth lost during PM = 299 (3.0 teeth/patient) Teeth lost due to PR = 259 (2.6 teeth/patient) 45 patients lost no teeth (45.0%) 23 patients lost ≥ 4 teeth (23.0%) 23.0% of patients accounted for 79.5% of all teeth lost due periodontal reasons (206)	University-based (USA)
McGuire & Nunn (1996b)	CS, retrospective design, maintenance regime at a 2–3-month interval, at least 5 years' duration (mean duration 9.9 years, range 5–16)	100 individuals, 65 females, number of smokers NR, aged 22–71 at the time of initial therapy, with chronic generalized moderate to severe adult periodontitis Teeth present after APT = 2509 (mean 25.1 teeth/patient)	Oral hygiene measures, scaling, selective root planing and tooth polishing	Total number of teeth lost during PM = 131 (1.3 teeth/patient) Teeth lost due to PR = NR 51 patients lost no teeth (51.0%)	Practice-based (USA)
McLeod et al. (1998)	CS, retrospective design, maintenance regime at a 3–6-month interval (mean 3.2 months), at least 5 years' duration (mean duration 12.5 years, range 5–29)	114 individuals, 57 females, number of smokers NR, aged 26–79 at the time of initial therapy, with moderate to advanced periodontitis Teeth present after APT = 2899 (mean 25.4 teeth/patient)	NR	Total number of teeth lost during PM = 220 (1.9 teeth/patient) Teeth lost due to PR = 152 (1.3 teeth/patient) 41 patients lost no teeth (36.0%) 18 patients lost ≥ 4 teeth (15.8%) 15.8% of patients accounted for 59.1% of all teeth lost (130)	University-based (USA)
Papantonopoulos (2004)	CS, retrospective design, maintenance regime at a 3–4-month interval, at least 5 years' duration (mean duration 6.5 years, range 5–8)	29 individuals, 14 smokers, aged 31–62 at the time of initial therapy, with advanced periodontal disease Teeth present after APT = NR (mean 24.1 teeth/patient)	Oral hygiene measures, scaling, professional tooth cleaning and selective root planing (in sites which bled upon probing).	Teeth lost during PM = 3 (0.10 teeth/patient) Teeth lost due to PR = NR 23 patients lost no teeth (88.5%) 3 patients lost teeth (11.5%)	Practice-based (Greece)
Tsami et al. (2009)	CS, retrospective design, maintenance regime at a 3–4-month interval, at least 8 years' duration (mean duration 10.8 years, range 8–16)	280 individuals, 154 females, 185 smokers, aged 43–62 at the time of initial therapy, with generalized severe chronic periodontitis Teeth present after APT = 5246 (mean 18.7 teeth/patient)	Oral hygiene measures, scaling and selective root planing.	Total number of teeth lost during PM = 918 (3.3 teeth/patient) Teeth lost due to PR = 378 (1.3 teeth/patient) Number of patients who lost no tooth = 127 Number of patients who lost ≥ 4 teeth = NR	Practice-based (Greece) Unpublished data were included following contact with author
Wood et al. (1989)	CS, retrospective design, maintenance regime at a 6, 6–9 or >9 month interval, at least 10 years' duration (mean duration 13.6 years, range 10–34)	63 individuals, 41 females, number of smokers NR, aged 24–67 at the time of initial therapy, with moderate periodontitis Teeth present after APT = 1607 (mean 25.5 teeth/patient)	NR	Total number of teeth lost during PM = 115 (1.8 teeth/patient) Teeth lost due to PR = 88 (1.4 teeth/patient) 25 patients lost no teeth (39.7%) 9 patients lost ≥ 4 teeth (14.3%) 14.3% of patients accounted for 54.5% of all teeth lost due periodontal reasons (48)	University-based (USA)

CS, case series; NR, not reported; APT, active periodontal therapy; PM, periodontal maintenance; PR, periodontal reasons.

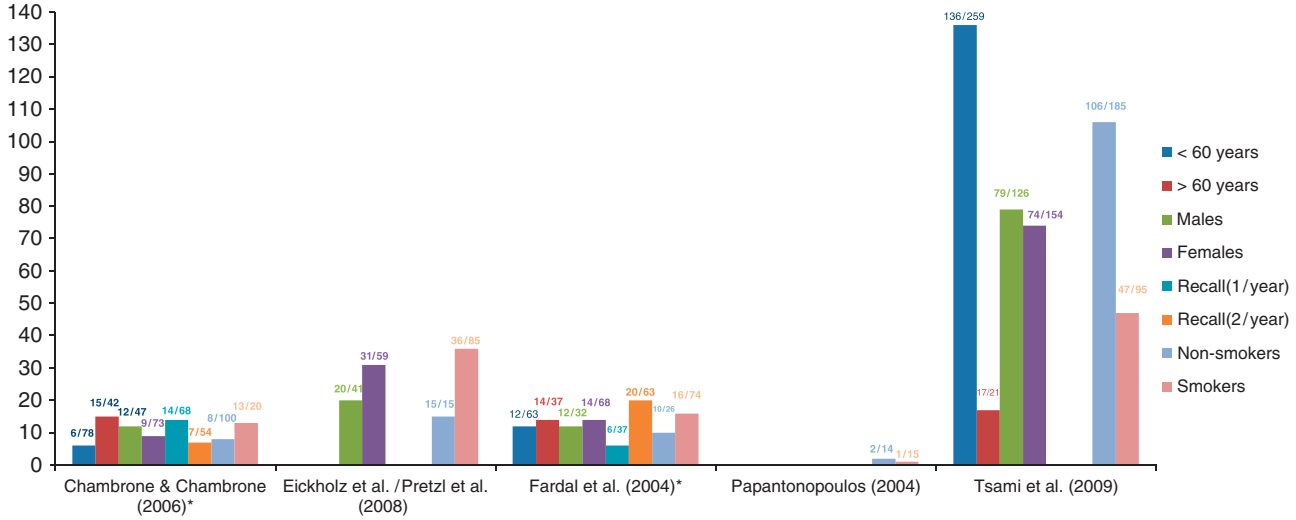

Fig. 2. Raw data of included studies reporting patient-related factors (patients who lost at least one tooth during periodontal maintenance/total number of patients; *studies reporting tooth loss exclusively due to periodontal reasons).

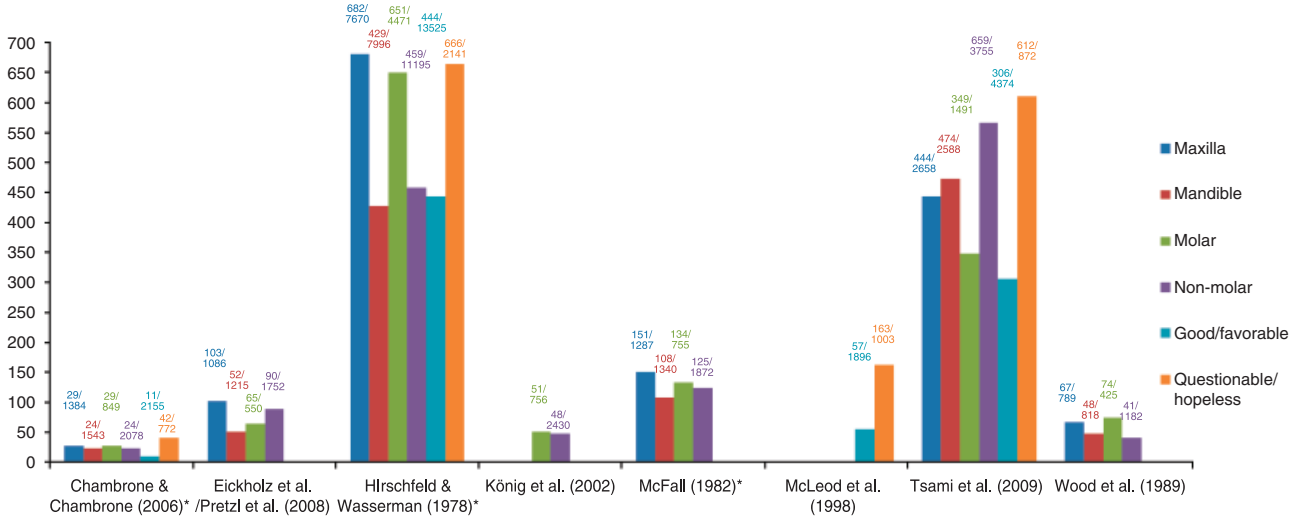

Fig. 3. Raw data of studies included reporting site-based data (i.e. tooth-related factors, teeth lost during periodontal maintenance/total number of teeth; *studies reporting tooth loss exclusively due to periodontal reasons).

years (OR = 7.1, CI: 1.8–28.6) and smoking (OR = 4.8, CI: 1.4–15.9) were found to be correlated with the number of teeth lost due to periodontal reasons (logistic regression analysis, $p < 0.05$).

Eickholz et al. (2008), Pretzl et al. (2008) – In the first paper, Poisson's regression analysis identified a higher plaque control record, irregular participation in PM, higher age, initial diagnosis, presence of interleukin 1 (IL-1) polymorphism, smoking and gender (female sex) as factors statistically significantly influencing tooth loss ($p < 0.05$). According to the authors, ''for aggressive and generalized severe chronic periodontitis, risk for tooth loss was doubled compared with moderate periodontitis''. In the second paper, these patient-related factors were entered into a tooth-related logistic multilevel regression analysis, were presence of the IL-1 polymorphism, initial diagnosis (i.e. aggressive or severe chronic periodontitis), smoking and gender failed to emerge as significant risk factors for tooth loss. On the other hand, irregular participation in PM (OR = 4.6), higher plaque control record during PM (OR = 1.8), age (OR = 1.1), baseline interproximal bone loss (OR = 2.4), presence of furcation involvement (OR = 2.1) and abutment tooth (OR = 1.74) were found to be positively related to total tooth loss (logistic multilevel regression analysis, $p < 0.05$). In addition, the original authors reported that only 11 patients lost ≥ 4 teeth. However, after analysing the unpublished data following contact with the author, it was found that 12 patients lost ≥ 4 teeth.

Fardal et al. (2004) – Five independent predictors of tooth loss (i.e. gender, age, maintenance, oral health status, family story and smoking) were entered in a logistic regression analysis. Male gender (OR = 2.8, CI: 1.0–8.1), age >60 years (OR = 4.02, CI: 1.35–11.95) and smoking (OR = 4.2, CI: 1.3–13.8) were found to be statistically associated with tooth loss due to periodontal reasons ($p < 0.05$). Data from overall tooth loss was not analysed by the authors.

Jansson & Lagervall (2008) – The longitudinal tooth loss was significantly associated with smoking (multiple step-

wise regression analysis, regression coefficient = 2.9 $p < 0.05$).

König et al. (2002) – The independent variables smoking, age, gender, number of teeth, and periodontal probing depth at initial examination, number of maintenance visits per year, oral hygiene, number of treating dentists, re-operation and antibiotic therapy were analysed via multiple regression analysis. Smoking and antibiotic therapy were considered to be associated with tooth loss during PM ($p < 0.05$).

Matthews et al. (2001) – The authors of this study performed independent *t*-tests or chi-squared tests to compare the outcomes between non-surgical and surgical patients. Compliance, gender and smoking had no effect on tooth loss ($p > 0.05$). For overall tooth loss, factorial ANOVA was performed to determine the possible predictors for the tooth loss. The variables entered in the model included initial clinical attachment loss (CAL), type of periodontal treatment (surgical or non-surgical), age and gender. Only initial attachment loss was found to be significant ($p < 0.05$), and also, patients with advanced attachment loss lost more teeth.

McGuire & Nunn (1996b) – Possible factors influencing tooth loss were evaluated using robust log rank tests and Cox proportional hazard regression models. Robust log rank tests indicated that initial probing depth, initial furcation involvement, initial mobility, unsatisfactory crown-to-root ratio and root form were all associated with an increased risk of tooth loss. In addition, smoking and an increased initial bone loss were found to be significantly associated with increased risk of tooth loss ($p < 0.05$).

Tsami et al. (2009) – This study used a logistic regression analysis model to assess the degree of association between tooth loss during PM and age, gender, initial tooth prognosis, participant's compliance with suggested maintenance visits, smoking and tooth type. Initial tooth prognosis and type, patients' compliance and smoking were associated with tooth loss during PM ($p < 0.05$).

Overall tooth loss during PM

Three studies did not report the number of teeth present after APT (Matthews et al. 2001, Papantonopoulos 2004, Jansson & Lagervall 2008), and one study reported only the mean number of teeth lost (Jansson & Lagervall 2008). Regarding the other 10 CSs, a total of 41,404 teeth in 1723 patients (1043 females and 680 males, aged 08–79 years at the time of initial therapy) were present after the completion of the APT (Table 1). During PM, 3919 teeth (9.5%) were lost, and of these, 2488 (6.8% of all teeth present after APT, excluding the data from McGuire & Nunn 1996b, Eickholz et al. 2008, Pretzl et al. 2008) were lost due to periodontal reasons (PR). In addition, the percentages of tooth loss varied from 3.1% (König et al. 2002) to 17.5% (Tsami et al. 2009) for total tooth loss during PM (all reasons), and from 1.5% (König et al. 2002, Fardal et al. 2004) to 9.8% (McFall 1982) for teeth lost due to PR (Table 1).

With respect to the number of teeth lost per patient and the percentages of patients who did not experience tooth loss during PM, both showed a marked variation. Practice-based studies have reported 0.1–3.3 teeth lost per patient (mean loss 1.4 teeth), while university-based trials have reported 0.7–3.0 teeth lost per patient (mean loss 1.8 teeth). Regarding the number of patients who did not lose teeth during maintenance, the findings ranged from 50.0% to 88.5% for practice-based studies and from 36.0% to 79.4% for university-based studies.

Periodontal treatment and PM

With respect to APT, all studies reported a similar treatment protocol based on oral hygiene instructions, scaling and root planning, tooth polishing, re-evaluation and periodontal surgery where indicated. Similarly, the majority of trials reported similar maintenance protocols based on scaling, root planning and tooth polishing as well. Only three CSs did not report the procedures performed during PM (Table 1).

Risk of bias in included studies

The risk of bias (quality assessment) of the included studies was evaluated using the data extracted from each trial (Fig. 4). Of the 13 included CS, four received an 8-point score (out of 11), one a 7-point score and five a 6-point score (Fig. 4). Consequently, ten studies were considered of medium methodological quality and three of low methodological quality. None of the studies was considered of high methodological quality.

Discussion

Summary of the main results

The results of this systematic review demonstrated that many patients did not lose teeth and only a minority of treated patients were responsible for the majority of tooth extractions during PM (Table 1). Only one study showed the contrary (Tsami et al. 2009). Overall, the pooled data suggested that some factors have been positively associated with tooth loss, such as inadequate plaque control, age, gender, initial attachment loss, presence of furcation involvement, baseline tooth mobility and tobacco smoking.

Quality of the evidence and potential biases in the review process

The risk of bias assessment showed that none of the studies reported a high methodological quality (Fig. 2). Therefore, the present review may lead to a ''welcome'' discussion about the local and systemic risk factors influencing tooth loss, the source of evidence available for analysis, the criteria applied to extract a tooth and the effects of long-term PM. Yet, it may also allow the formulation of the following question: what is the value of the reviewed studies (if there is any)? CS may have serious methodological flaws, and their inclusion in a systematic review may lead to weak evidence and adds little to a general knowledge of a problem (Needleman 2002, 2005, Chambrone et al. 2009b,

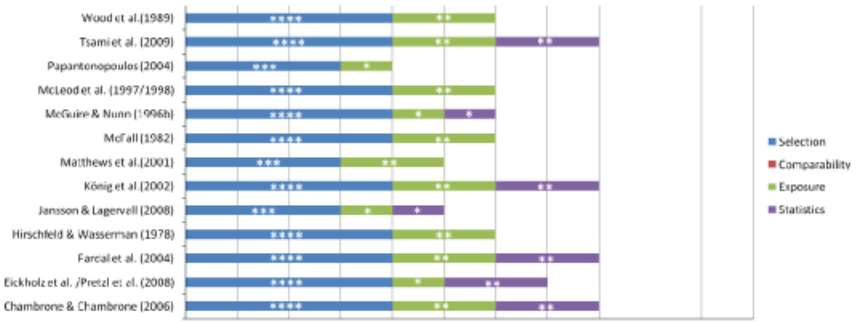

Fig. 4. Methodological quality of included studies (*,**,*** assigned to respective study).

2010). Even if tooth loss is reported according to age, gender and smoking, for instance, studies' results may be affected by different types of bias such as publication and selection bias. Moreover, there are several problems with the reviewed type of studies that are resolved up to now, i.e. socioeconomic factors (what would be the outcome of an individual patient if untreated), the age factor (a cut-off of 60 years may be considered a trick to make results significant), smoking factor (how the individual studies defined a subject as a smoker and how the investigators ascertained the accuracy of this classification), diagnosis of periodontitis (mixing different types of patients may overestimate or underestimate tooth loss) and many more. On the other hand, although the exclusion of such studies allows bias protection, it can also lead to a potential loss of the evidence base when adequate sources of evidence are not available.

As mentioned before, it was not possible to perform comparisons between studies, i.e. meta-analysis, due the substantial degree of heterogeneity found in terms of the studies' methodology. Systematic reviews of observational studies are important but meta-analysis of such data is questionable in view of the potential bias and the lack of control of confounders. Where the studies are prospective and well designed, it might be possible to run such an analysis. However, these quantitative estimates can lead to spurious precision and invalid estimates. Moreover, such data are likely to be seized upon by readers less aware of these methodological limitations, as well as when the data are exclusively from retrospective case series, the quality of data is even more compromised. Therefore, the most transparent approach was to present the data without meta-analysis.

In addition, only studies including patients who attended at least 5 years of PM were included in order to minimize heterogeneity and to allow a follow-up long enough for the outcome to occur (i.e. tooth loss). However, this inclusion criterion could have eliminated data from studies that could be suitable for conducting meta-analyses. As such, the greatest strength of the current paper is its role in calling attention to the paucity and the need for well-designed prospective observational studies (i.e. cohort studies) that will properly evaluate and identify the presumed factors influencing tooth loss during long-term PM. Nevertheless, it is important to be clear that a cohort study has both an exposed group (i.e. patients subjected to periodontal therapy) and a non-exposed comparison. The non-exposed comparison group will need some reflection, but for instance, it could include patients attending regular dental care without a history/diagnosis of periodontitis. Randomized-controlled trials may also be designed and conducted to evaluate different regimens of PM. Conversely, there is an obvious dilemma of performing an RCT with a follow-up of 5–10 years. Such a study would be quite expensive and difficult to fund.

Agreements and disagreements with other studies or reviews

The results of this review demonstrated that long-term PM may decrease the levels of tooth loss. However, nobody knows anything of the ontogenesis of participants irrespective of whether they were treated or not including their – presumably – positive health awareness facilitating adherence to the maintenance scheme. Furthermore, periodontitis progression is not distributed equally among patients, but accumulates in groups of distinct risk patients.

It was found that more molar and maxillary teeth were lost during PM (Fig. 2), but such a loss was probably associated with anatomical features (i.e. furcation area) and disease progression (Huynh-Ba et al. 2009). Furthermore, it was evident from the studies included that teeth initially assigned as hopeless were not extracted due to the patients' desire to maintain them (McGuire & Nunn 1996b, Chambrone & Chambrone 2006). Questionable-hopeless teeth were the teeth most frequently lost while only a small group (2.9%) of teeth initially judged to have a good/favourable diagnosis were extracted. However, approximately 3/4 (73.9%) of all teeth assigned as questionable or hopeless were not lost. Conversely, particularly, the initial prognosis is a difficult ''risk factor'' to be compared between studies and some conditions need to be questioned: did all studies included use the same criteria for prognosis? No they did not. Tooth loss should be evaluated using separate tooth-level factors (e.g. probing depth, interproximal bone loss, tooth mobility) instead of using composite prognosis codes. For this reason, the question becomes: what is hopeless prognosis? Most classifications (e.g. McGuire & Nunn 1996b, Tsami et al. 2009) reported define ''inadequate attachment to maintain the tooth in health, comfort and function''. This is very imprecise and cloudy.

Regarding the type of periodontal therapy performed, all of the studies included patients subjected to diverse surgical procedures, such as gingivectomy, open flap debridement with or without osseous surgery and bone grafting. However, the results from surgical procedures performed before 1956 (Hirschfeld & Wasserman 1978) cannot be compared with those performed in the late 1980s (Chambrone & Chambrone 2006). With respect to tobacco smoking, information regarding smoking habits was only obtained through the data available from the patients' records. In spite of this limitation, smokers were at an increased risk of losing teeth.

In addition, it has been shown that regular PM provided by a periodontal specialist could not be comparable to a mere tooth cleaning that may be called ''prophylaxis'' in casual talk. The results of the present review confirm that both private and university-based practices were efficient in preventing tooth loss, but inter-study variations were also evident. Such variations may represent a limitation in comparing individual tooth loss between different populations.

Authors' conclusions

Although some patient- and tooth-related factors were associated with tooth loss during PM (e.g. age >60, smoking, initial tooth prognosis, tooth type and tooth location), there are no prospective cohort studies focusing on these predictors. This issue needs to be considered when interpreting the present findings. Overall, long-term periodontal maintenance maintained periodontal health and prevented tooth loss in most patients. These findings led to low rates of tooth loss due to periodontal reasons.

Implications for practice

Following initial APT, all patients must be instructed to continue receiving periodic PM. Patients who smoke should be encouraged to quit smoking. Although smoking cessation cannot reverse the effects of smoking immediately, it may improve tooth survival in the future and patients' overall health.

Implications for research

Well-designed prospective cohort studies are required to confirm which pre-

dictors will lead to periodontal tooth extraction. Also, the allocation of patients into subgroups according to the type of periodontitis (e.g. aggressive or chronic) and smoking frequency (i.e. light or heavy smokers) will allow more accurate evaluations and future comparisons via meta-analyses.

Case–control trials and practice-based studies reporting results achieved in daily practice may be of interest as well. However, CS should at least be prospective. In addition, multicentre studies may be required to increase the number of patients and to achieve adequate statistical power.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix S1. Newcastle–Ottawa Quality Assessment Scale adapted for this review.

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Clinical Relevance

Scientific rationale for the study: During periodontal maintenance, different patient- and tooth-related factors may be associated with tooth extraction. However, evidence focusing on the possible predictors of tooth loss during long-term periodontal maintenance has not been systematically assessed as yet.

Principal findings: The results of this review have shown that the majority of patients lost no teeth during periodontal maintenance. Different patient-related risk factors (e.g. smoking and age) and tooth-related factors (e.g. tooth type and location and the initial tooth prognosis) may contribute to tooth loss during long-term periodontal maintenance. However, these results should be interpreted with caution due primarily to the retrospective nature of the data and secondarily due to the considerable heterogeneity found between studies.

Practical implications: Long-term periodontal maintenance can prevent tooth loss in the majority of patients. Further research is recommended to adequately confirm and identify the possible risk factors associated with tooth loss due to periodontitis.