PATIENT-RELATED AND TOOTH-RELATED FACTORS AS PREDICTORS FOR TOOTH LOSS IN PERIODONTITIS PATIENTS: A SYSTEMATIC REVIEW

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Introduction: The treatment of periodontitis aims to prevent further disease progression, to minimize symptoms and perception of the disease, possibly to restore lost tissues and to support patients in maintaining a healthy periodontium. Management of chronic periodontal disease requires a combination of therapeutic modalities and a lifelong commitment to periodontal self-care.

Objectives: The aim of this study is to evaluate predictors for tooth loss in patients previously diagnosed with periodontitis. This systematic review covers studies of over 10 years of follow up.

Methods: Electronic literature search was conducted on 19/02/2024 by one author across several databases, including Medline (PubMed), Embase, and Google Scholar, including longitudinal studies investigating the association between predictors and tooth loss in periodontitis patients. A total of 594 publications were screened, and three reviewers analyzed the articles and extracted the data. Of these, 17 studies met the inclusion criteria.

Results: A total of 17 articles were included in this systematic review. The mean year of publication of the included studies was 2014. The mean follow-up period was 13.8 years. The studies involved a total of 2,633 participants. The mean sample size was 154 participants. Patients' mean age was 42.5 years.

Conclusions: Older, males, smokers or diabetic patients, with irregular attendance to supportive periodontal therapy and teeth with high probing depth, mobility, or molars, especially with furcation involvement, are major modifiable risk factors for tooth loss.

Keywords: Periodontal therapy, periodontitis, risk factor, tooth loss

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Conflicts of interest:
The authors declare no conflicts of interest.

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FACTEURS LIÉS AUX PATIENTS ET AUX DENTS COMME PRÉDICTEURS DE LA PERTE DES DENTS CHEZ LES PATIENTS ATTEINTS DE PARODONTITE: UNE REVUE SYSTÉMATIQUE

Introduction: Le traitement de la parodontite vise à prévenir la progression de la maladie, à minimiser les symptômes et la perception de la maladie, éventuellement à restaurer les tissus perdus et à aider les patients à maintenir un parodonte sain. La prise en charge de la parodontite chronique nécessite une combinaison de modalités thérapeutiques et un engagement à vie envers l'auto-soin parodontal.

Objectifs: L›objectif de cette étude est d›évaluer les prédicteurs de la perte dentaire chez les patients précédemment diagnostiqués avec une parodontite. Cette revue systématique couvrira les études ayant un suivi de plus de 10 ans.

Méthodes: Des recherches bibliographiques électroniques ont été effectuées **le** 19/02/2024 par un auteur dans plusieurs bases de données, y compris Medline (PubMed), Embase et Google Scholar, incluant des études longitudinales examinant l'association entre les prédicteurs et la perte dentaire chez les patients atteints de parodontite. Un total de 594 publications a été examiné, et trois évaluateurs ont analysé les articles et extrait les données. Parmi ces publications, 17 études ont répondu aux critères d'inclusion.

Résultats: Un total de 17 articles a été inclus dans cette revue systématique. L›année moyenne de publication des études incluses était 2014. La durée moyenne du suivi était de 13,8 ans. Les études ont impliqué un total de 2 633 participants, avec une taille d›échantillon moyenne de 154 participants. L›âge moyen des patients était de 42,5 ans.

Conclusion: Les facteurs de risque majeurs pour la perte dentaire incluent les patients plus âgés, les hommes, les fumeurs ou les patients diabétiques, avec les patients ayant une fréquence irrégulière des visites de maintenance et des dents avec une profondeur de poches élevée, une mobilité, ou des molaires, en particulier avec une implication furcation.

Mots clés: Thérapeutique parodontale, parodontite, facteur de risque, perte dentaire

Introduction

Periodontal disease (PD) is an infectious disease characterized by inflammation of the tooth-supportive tissues, which can lead to destruction of the periodontal ligament and alveolar bone [1]. Periodontitis is the sixth most prevalent disease in people nowadays, affecting billions of individuals and generating considerable healthcare costs [2, 3]. In many cases and especially if untreated or unsuccessfully treated, the disease leads to tooth loss [4].

The treatment of periodontitis aims to prevent further disease progression, to minimize symptoms and perception of the disease, possibly to restore lost tissues and to support patients in maintaining a healthy periodontium [1]. Management of chronic periodontal disease requires a combination of therapeutic modalities and a lifelong commitment to periodontal self-care. The relationship between oral infection/inflammation and non-communicable is present and further discussed in this thesis [5].

A range of variables play a role in tooth loss in patients diagnosed with periodontitis, and their knowledge and association to tooth loss is important to make informed decisions and to improve treatment modifications. If tooth loss is unlikely, tooth retention via active and supportive periodontal therapy (APT, SPT) offer the most effective long-term solution [6]. SPT sessions incorporate assessment of periodontal and general health, motivation to self-performed oral hygiene and risk factor control, professional mechanical plaque removal, and subgingival instrumentation of residual pockets [7]. Several definitions of non-compliance to SPT have been proposed in the literature, with a variable impact on the risk ratio for tooth loss depending on the level of stringency (strict or range) to define a non-compliant patient [8, 9].

Tooth loss adversely affects masticatory function and phonation, thereby influencing both self-perception and external perceptions. This impairment can detrimentally impact multiple dimensions of quality of life, including the capacity and motivation to engage in social activities and to consume food requiring significant mastication. The resulting decline in functional and psychosocial well-being may contribute to depressive symptoms, social isolation, and compromised nutritional status [10].

The goal of periodontal therapy is to maximize the longevity and survival of the natural dentition and maintain it in a healthy, functional and pain-free state [11]. There is a void in the literature addressing the tooth loss rate in the adult population and its potential associated factors such as diabetes, smoking, bruxism, cardiovascular diseases, and also the effect of supportive periodontal therapy on these factors and its contribution to arrest periodontitis progression and minimizing tooth loss.

The objective of this study is to systematically evaluate tooth-related and patient-related predictors of tooth loss in patients with periodontitis and to aggregate data on how they relate to tooth loss.

Materials and Methods

This review aimed to study in periodontitis patients who underwent active periodontal therapy and maintenance (P), how do patient-related and tooth-related factors influence tooth loss over various follow-up periods (minimum of 10 years).

This systematic analysis was performed according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement. Ethical Committee approval of Saint-Joseph University of Beirut, (approval number USJ-2023-61).

Eligibility criteria and study selection

The included articles were as follows: Studies reporting dentate humans with periodontitis which received APT and SPT, without further specification for diagnoses and treatment concepts. Prospective and retrospective observational studies as well as interventional longitudinal studies. Studies with a minimum follow-up period of 10 years that examined the relationship between predictors (independent variables) and tooth loss (outcome). This criterion was set because we anticipated that tooth loss would not occur frequently enough in short-term studies and because dentists need information for making long-term decisions. Notably, many of the studies ultimately included had even longer follow-up periods, providing insights into long-term associations between predictors and tooth loss. Studies were required to use a multivariable model to assess the relationship between predictors and the outcome, incorporating at least three predictors. Specific criteria on how tooth loss was measured or reported was not imposed, anticipating a wide variety of definitions and methodologies.

Only studies fulfilling all of the above-described criteria were included.

The excluded articles were as follows: Systematic reviews and narrative reviews. Articles with the presence of a more-recent follow-up publication including the same patient pool. Studies reporting tooth loss rates associated to only one factor and studies including self-reported tooth loss rates. Studies not published in English; the language restriction was a pragmatic decision and may result in under-detection of eligible studies.

Literature search protocol

Electronic and manual literature search was conducted by one author (CD) in several databases, including Medline (PubMed), Google Scholar and Cochrane library.

The PubMed database was searched for papers using the following strategy only English articles

were filtered: ("tooth loss rate"[Title] OR "tooth loss"[Title] OR "tooth morbidity"[Title] OR "dental morbidity"[Title]) AND ("potential factors"[Title] OR "associated factors"[Title] OR "risk factors"[Title] OR "periodontal"[Title/Abstract] OR "periodontitis"[Title/Abstract] OR "active therapy"[Title/Abstract] OR "long term maintenance"[Title] OR "smoking"[Title] OR "age"[Title] OR "supportive periodontal therapy"[Title] OR "diabetes"[Title] OR "bruxism"[Title])

Screening and data collection

Data were independently extracted by two reviewers (CD and CC) in piloted forms focusing on the main outcomes of the systematic review (TLR and different factors).

Year, country, mean age, chronic periodontitis or aggressive periodontitis, sample size, mean follow up in years, initial number teeth, number of teeth lost, exclusion or inclusion of 3rd molars, tooth loss per pt./year, specialized care or general practice and predictor variables related to TLR were also extracted and recorded in an Excel sheet.

Three reviewers (CD, CC and CA) evaluated the titles and abstracts of the studies. Papers selected by either reviewer were included for full-text analysis. Any discrepancies were resolved through discussion between the two reviewers (CD and CC) after reviewing the entire manuscript; unresolved disagreements resulted in the decision to include the article. Manually screening the references of the included articles references to identify possible additional articles.

Methodological quality assessment

The following criteria was used to classify the potential risk of bias for each article, as applied in a previous review [12]: Random sample selection in the population. Definition of inclusion/exclusion criteria. Report of losses to follow-up (monitoring). Validated measurements obtained. Statistical analysis.

Studies meeting all of the above criteria were classified as having low risk of bias, those that met all but one of the criteria were classified as having a moderate risk of bias, and those that did not meet two or more criteria were classified as presenting a high risk of bias.

Data extraction

From the included articles, the following data were extracted and recorded on standardized forms:

- Author.
- Year of publication.
- Study design.
- Country.
- Mean age.
- Diagnosis: chronic periodontitis or aggressive periodontitis.
- Sample size.
- Mean follow up in years.
- Initial number teeth.
- Number of teeth lost.
- Exclusion or inclusion of 3rd molars.
- Tooth loss per pt./year.
- Specialized care or general practice.
- Predictor variables related to TLR.

Data synthesis

A quantitative assessment of the TLR for data synthesis was realized in the present systematic review.

In the systematic review, variables related to teeth and patients were categorized for analysis. At the tooth level, the factors included endodontic treatment (presence of root fillings or periapical lesions), tooth type (molars or multi-rooted teeth vs. other types), maximal probing pocket depth, furcation involvement, and mobility. At the patient level, comparisons were made based on sex (male vs. female), age, compliance (compliant vs. non-compliant, measured by annual SPT visits), smoking status (current vs. never/former smokers) parafunction (presence vs. absence), diabetes mellitus (present vs. absent), and CVD (presence or absence). Additional predictors such as bleeding on probing, oral hygiene indices, tooth abutment status, and follow-up periods were reported in fewer than three studies and were not included, as the limited data were unlikely to yield reliable conclusions.

Statistical analysis

The literature identified in this review does not meet criteria required for quantitative data or meta-analysis. Furthermore, the heterogeneity of studies (study design, study population, follow-up times, therapy definition, and parameters reported) prevents the plotting of outcomes to feature results. Therefore, descriptive methods were mainly used to present the data.

Results

Study Selection and Characteristics

The electronic search yielded a total of 594 papers, of which 55 were selected for full-text review following title and abstract screening. After further assessment, 34 articles were excluded for reasons such as duplicates, lack of correlation between risk factors and tooth loss (TL), absence of a clear definition of compliance cases, or failure to specify the SPT (Supportive Periodontal Therapy) recall interval. Ultimately, 17 articles were included in this systematic review (see Tables 1 and 2 and Figure 1).

The mean publication year of the included studies was 2014, with the range spanning from 2006 to 2023. The average follow-up period across the studies was 13.8 years (range: 10–25.5 years). The studies involved a total of 2,633 participants, with a mean sample size of 154 (range: 25–500). The mean age of the patients was 42.5 years, with the range of study means falling between 31 and 66.6 years. Among the included studies, three focused exclusively on chronic periodontitis, two on aggressive periodontitis, and the remaining studies either assessed both types or did not provide information on the disease type. The mean annual tooth loss per patient was 0.1147 (range: 0.01–0.36).

Table 1. Quality assessment of the selected studies [12].

Author and year	Random patient selection	Defined inclusion/exclusion criteria	Reported follow up	Validated measurements	Statistical analysis	Estimated potential risk of bias
Baumer et al. 2011	No	Yes	Yes	Yes	Yes	Moderate
Baumer et al. 2019	No	Yes	Yes	Yes	Yes	Moderate
Carollo-Bittel et al. 2011	No	No	Yes	Yes	Yes	Moderate
Chambrone et al. 2006	No	Yes	No	Yes	No	High
Di Febo et al. 2015	No	No	Yes	Yes	Yes	High
Diaz Faes et al. 2016	Yes	Yes	Yes	Yes	Yes	Low
Eickholz et al. 2008	No	Yes	Yes	Yes	Yes	Moderate
Faggion et al. 2007	No	No	Yes	Yes	Yes	High
Graetz et al. 2015	Yes	Yes	No	Yes	Yes	Moderate
Martinez-Canut et al. 2015	No	Yes	Yes	Yes	Yes	Moderate
Megarbane et al. 2023	No	Yes	Yes	Yes	Yes	Moderate
Muller et al. 2013	No	Yes	Yes	Yes	Yes	Moderate
Ng et al. 2011	No	Yes	Yes	Yes	Yes	Moderate
Petsos et al. 2021	No	Yes	Yes	Yes	Yes	Moderate
Pretzl et al. 2018	Yes	Yes	Yes	Yes	Yes	Low
Ravald et al. 2012	No	Yes	Yes	Yes	Yes	Moderate
Salvi et al. 2014	No	No	Yes	Yes	Yes	High

Quality Assessment of Selected Studies

From the articles included in the present review, the quality evaluation showed that 2 studies presented low risk of bias, 11 studies presented with moderate risk of bias, and 4 studies presented with high risk of bias (Table 1).

Associations of Tooth Loss with Patient-Level Parameters

Seven patient-level parameters were investigated for their association with tooth loss across the included studies.

The influence of **age** on tooth loss was explored in five studies, all of which concluded that tooth loss rates increased with age [13–16]. However, Petsos et al. (2021) found no significant relationship between age and tooth loss in their study [16].

Similarly, the **gender** factor was examined in nine studies, with most reporting that females experienced a lower rate of tooth loss than males [14, 17–24]. Again, Petsos et al. (2021) was the exception, showing no significant gender-related differences in tooth loss [16].

In relation to **diabetes**, eight studies were reviewed. Six of these found that diabetic patients exhibited a higher rate of tooth loss compared to non-diabetic patients [15, 20–22], while Eickholz et al. (2008) and Petsos et al. (2021) reported no significant association between diabetes and tooth loss [14, 16].

Cardiovascular disease was assessed in two studies, both of which found that patients with heart disease or cardiovascular conditions had a higher rate of tooth loss [15, 24].

The association between **smoking** and tooth loss was examined in 14 studies. Twelve studies concluded that smokers experienced a higher rate of tooth loss compared to non-smokers or former smokers [14, 18–21, 23–25, 27–28], with only two studies failing to demonstrate a significant correlation between smoking and tooth loss [13, 15].

Eleven studies assessed the impact of **patient compliance** on tooth loss. Ten of these studies found that patients who were irregular in their visits (less than one visit per year) experienced higher rates of tooth loss than those who attended regular follow-up appointments (one or two visits per year) [13–15, 18, 19, 21, 23–25, 28]. The exception was the study by Ng et al. (2011), which found that irregular compliers had lower rates of tooth loss than regular compliers [22].

Lastly, **parafunction** or **bruxism** was studied by Di Febo et al. (2015) and Megarbane et al. (2023), both of which reported that patients with parafunctional habits had a higher rate of tooth loss [13, 15].

Associations of Tooth Loss with Tooth-Level Parameters

The relationship between tooth-level parameters and tooth loss was assessed in relation to six factors.

The influence of **endodontic treatment** on tooth loss was studied in three articles. All three studies found that teeth treated endodontically had a higher likelihood of being lost compared to vital teeth [13, 20, 29].

Furcation involvement was explored in four studies, all of which concluded that teeth with Class III furcation involvement had a higher risk of tooth loss compared to those without furcation involvement [16, 17, 20, 23].

Pocket depth (PD) was examined in two studies, both of which found that shallower pocket depths were associated with lower rates of tooth loss, while pockets greater than 6 mm (PD >6 mm) were linked to higher tooth loss rates [26, 28].

Four studies assessed the relationship between **tooth type** and tooth loss. Di Febo et al. (2015), Faggion et al. (2007), and Baumer et al. (2019) found that multi-rooted teeth (those with two or three roots) had a higher risk of tooth loss compared to single-rooted teeth [13, 25, 29]. However, Petsos et al. (2021) found no significant difference between multi-rooted and single-rooted teeth in terms of tooth loss [16]. Baumer et al. (2019) also concluded that maxillary teeth were more prone to being lost than mandibular teeth [25].

The effect of **tooth mobility** on tooth loss was investigated in three studies, all of which agreed that teeth with mobility degrees II and III had a higher risk of being lost compared to non-mobile teeth [16, 20, 29].

As for **abutment teeth** they were studied in one article, which found that abutment teeth had a higher rate of tooth loss than non-abutment teeth [25].

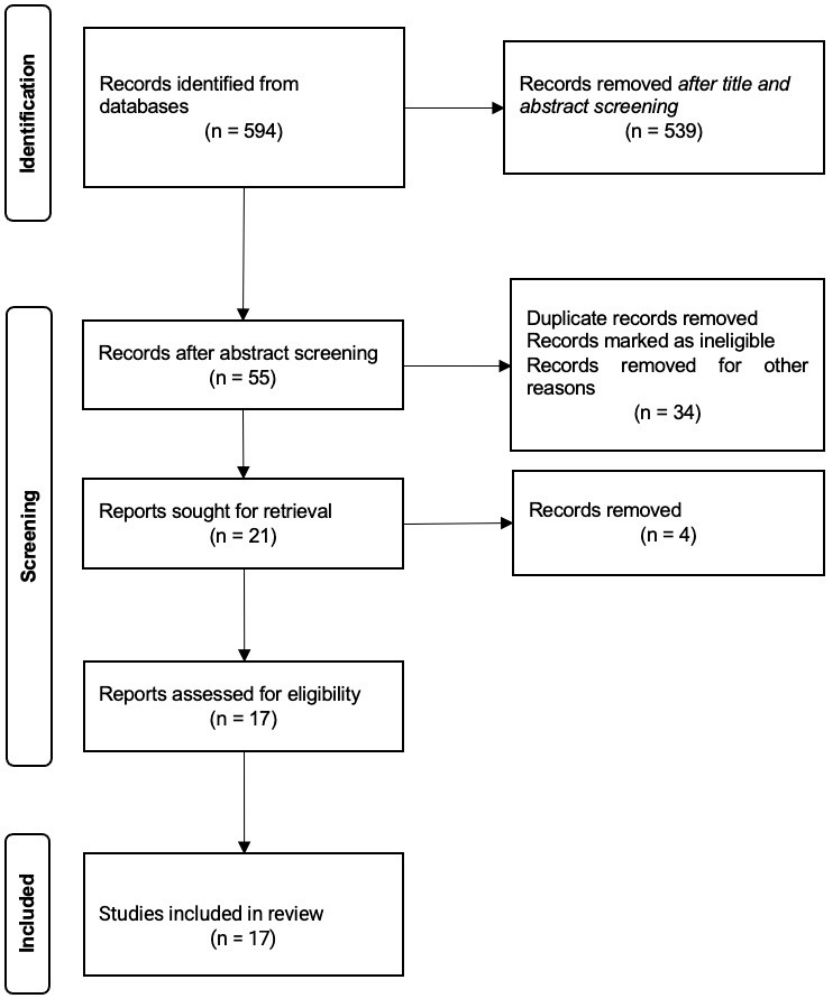

Figure 1. Flow chart of the literature search

Table 2. Study characteristics of all included studies in the analysis.

Study	Year	Country	Mean Age	CP / AP	Sample size	Mean follow-up (years)	Initial number of teeth	Number of teeth lost at follow-up	3rd molars	Tooth loss rate	General practice or specialized care	Predictor variable	Outcome measure	Conclusion
Baumer et al. 2011	2011	Germany	31	AP	84	11	2154	113	Excluded	0.13	Specialized	Gender	OR	Females had a lower tooth loss rate than makes
												Smoking	OR	Smokers had a higher tooth loss than non-smokers
												Furcation Involvement	OR	Teeth with furcation involvment impacted negatively long term survival of tooth
												Molar	OR	Molar teeth had a higher tooth loss than premolars
Baumer et al. 2019	2019	Germany	35.3	AP	100	25.5	2153	227	Excluded	0.09	Speialized	Smoking	HR	Smokers had a higher tooth loss rate than non-smokers
												Attendence to SPT	HR	Patients attending SPT regularly lost fewer teeth than patients who were not seen by a periodontist on a biannual basis
												Maxillary Teeth	HR	Increased tooth loss for maxillary teeth
												Premolars and Molars	HR	Increased tooth loss for premolars and molars compared to anterior teeth
												Abutment Teeth	HR	Abutment teeth significantly have a higher risk of tooth loss

Carollo-Bittel et al. 2011	2011	Switzerland	-	CP	89	10	NA	NA	Excluded	0.10	Specialized	Smoking	OR	Smokers had a higher tooth loss than non-smokers
												Pocket Depth	OR	PD ≥6 mm increased tooth loss
Chambrone et al. 2006	2006	Brazil	39	CP	120	17	2927	111	Included	0.05	Specialized	Gender	OR	Female had a lower tooth loss than males
												Smoking	OR	Increase tooth loss during periodontal maintenance
												Compliance	OR	Two visits a year decreased tooth loss rate compared to one visit a year
Di Febo et al. 2015	2015	Italy	42	na	100	20	948	94	NA	0.05	General	Age	OR	Tooth loss rate increases with age
												Smoking	OR	No significant difference between smokers and non smokers
												SPT	OR	No significant difference was found between SPT every three or every six months
												Multi-rooted teeth	OR	Teeth with three roots had a higher risk of tooth loss
												Endodontic Treatment	OR	Endodonticly treated teeth had a higher tooth loss than non-endodonticly treated teeth

												Para-function	OR	Patients with parafunction had a higher tooth loss
												Gender	OR	Female had a lower tooth loss than males
Diaz Faes et al. 2016	2016	Spain	31	AP	25	11	656	28	Ex-cluded	0.11	Special-ized	Gender	OR	Female had a lower tooth loss than males
												Smoking	OR	Smokers had a higher tooth loss rate than non smokers
												Compli-ance	OR	Patients having a regular supportive care programme had a lower tooth loss rate
Eick-holz et at 2008	2008	Germa-ny	47	-	100	10	2246	155	Ex-cluded	0.16	Special-ized	Compli-ance	RR	Regular SPT and effective oral hy-giene are effective tools to reduce tooth loss
												Smoking	RR	Smokers had a higher tooth loss rate than non-smokers
												Gender	RR	Female had a lower tooth loss than males
												Age	RR	Tooth loss rate increases with age
												Diabetes	RR	No association between tooh loss and diabetes

Faggion et al. 2007	2007	Germany	47	-	198	12	4393	249	Excluded	0.11	Specialized	Diabetes	OR	Diabetic patients had a higher tooth loss than non-diabetic patients
												Mobility	OR	Class III mobility teeth had a higher tooth loss
												Molar	OR	Multirooted teeth had a higher tooth loss
												Endodontic Treatment	OR	Endodonticly treated teeth had a higher tooth loss than non-endodonticly treated teeth
Graetz et al. 2015	2015	Germany	46	Both	379	20	1892	357	Excluded	0.05	Specialized	Furcation Involvement	HR	Class III furcation involvment had a higher tooth loss rate than teeth with no furcation involvment
												Mobility	HR	Teeth with mobility (regardless of classification) affected the tooth loss rate
												Endodontic Treatment	HR	Endodonticly treated teeth had a higher tooth loss than non-endodonticly treated teeth
												Gender	-	Female had a lower tooth loss than males
												Smoking	-	Smokers had a higher tooth loss rate than non-smokers

												Diabetes	-	Diabetic patients had a higher tooth loss than non-diabetic patients
Martinez-Canut et al. 2015	2015	Spain	40	Both	500	20	12595	640	Excluded	0.05	Specialized	Smoking	RR	Smokers had a higher tooth loss rate than non-smokers
												Compliance	RR	Irregular compliers had higher tooth loss than regular compliers
Megarbane et al. 2023	2023	Lebanon	52.06	Both	192	24.89	4447	423	Excluded	0.16	Specialized	Smoking	-	No significant difference between smokers and non smokers
												Compliance	-	Irregular compliance was identified as a significant risk factor for tooth loss
												Bruxism	-	Bruxers had an incresed tooth loss risk
												CVD	-	CVD had an incresed tooth loss risk
												Age	-	Tooth loss rate increases with age
												Diabetes	-	Diabetic patients had a higher tooth loss risk than non-diabetic patients

Muller et al. 2013	2013	Germany	48	Both	90	10	2230	387	Excluded	0.36	Specialized	Gender	RR	Female had a lower tooth loss than males
												Smoking	RR	Smokers had a higher tooth loss rate than non-smokers
												Diabetes	RR	Diabetic patients had a higher tooth loss than non-diabetic patients
												Compliance	RR	Fully compliant platient had a lower tooth lost rate than partial compliers
Ng et al. 2011	2011	Singapore	45	CP	273	11	6726	253	Included	0.09	Specialized	Diabetes	OR	Diabetic patients had a higher tooth loss than non-diabetic patients
												Gender	OR	Female had a lower tooth loss than males
												Compliance	OR	Irregular compliers had lower tooth loss than regular compliers
Petsos et al. 2021	2021	Germany	55.2	Both	97	10	2323	119	Excluded	0.12	Specialized	Diabetes Mellitus	OR	Diabetes was not found to be a prognostic related tooth factor
												Age	OR	No relation was found between age and tooth loss
												Sex	OR	No significant difference between females and males

												Type of teeth	OR	No significant difference between multi- and single rooted teeth
												Mobility	OR	Tooth mobility degrees I and II had a higher tooth loss than no mobility
												Fur-cation Involve-ment	OR	Class III furcation involvment had a higher tooth loss rate than teeth with no furcation involv-ment
Pretzl et al. 2018	2018	Germa-ny	66.6	AG/ CP	70	20	1438	201	ex-cluded	0.14	Special-ized	Compli-ance	-	compliers had a lower tooth loss rate than non com-pliers
												Age	-	Tooth loss rate increases with age
												Sex	-	Female had a lower tooth loss than males
												Smoking	-	Smokers had a higher tooth loss rate than non-smokers
												Diabetes mellitus	-	Diabetic patients had a higher tooth loss than non-dia-betic patients
												Heart Diseases	-	Heart diseases were associated with an increased tooth loss

Ravald et al. 2012	2012	Swe-den	52	na	64	13	1537	211	na	0.23	General	Compli-ance	OR	SPT visists once or twise per year had a lower tooth loss than patients hav-ing SPT less than one time per year
												Smoking	OR	Smokers had a higher tooth loss than non-smokers
												Pocket Depth	OR	Pocket depth 4-6 had a lower tooth loss than PD >6mm
Salvi et al. 2014	2014	Swit-zerland	na	Both	152	12	113	17	Ex-cluded	0.01	Special-ized	Fur-cation Involve-ment	OR	Class III furcation involvment had a higher tooth loss rate
												Smoking	OR	Smokers had a higher tooth loss than non-smokers
												Compli-ance	OR	Irregular compliers had higher tooth loss than regular compliers
												Gender	OR	Female had a lower tooth loss than males

Discussion

Predicting the onset, progression, and eventual tooth loss due to periodontitis is crucial for dentists when planning treatments and communicating risks to patients. A systematic review has evaluated the tooth loss and disease progression in relation to several patient and tooth related factors [30]. However, there has not been an updated review for predictors of tooth loss with at least, a 10 years of follow-up on these predictors. We conducted a systematic review of studies on tooth loss in periodontitis patients to highlight both agreement and disagreement among the research findings.

The aim of this systematic review was to analyze and compare TL rates in different patients with different systemic, local and tooth related factors. Literature review search revealed wide heterogenicity between studies in terms of factors studied, population studied, and study design. All patients included in the studies were previously diagnosed with periodontal disease, then treated surgically and/or non-surgically, and then enrolled in a maintenance program. The active periodontal therapy preformed in the different studies was not taken into consideration due to its heterogenicity and rather focus more on the potential predictors for tooth loss. Aging significantly impacts periodontal health, with various factors contributing to increased susceptibility to the degradation of periodontal disease thus leading to tooth loss. These include changes in immune response, hormonal fluctuations, and the increased prevalence is partly attributed to cumulative exposure to risk factors such as poor oral hygiene, tobacco use, systemic conditions, and genetic predisposition over time. In the present study, only Petsos et al. (2021) found no correlation between increased TL [16]. Most of the literature found that the increase of age did influence on tooth loss rates [13–16]. The disagreement with Petsos et al. could be due to different sample size selection (n=97) and different inclusion and exclusion criteria for this study. Homogenous results were found concerning the gender's effect on tooth loss rates. In fact, females had a lower tooth loss than males [14, 17–24] this might be because of social habits, oral hygiene and systemic risk factors and that females are more proactive in seeking dental treatments. However, these patterns may vary across different populations and healthcare systems, as in some regions men may face greater barriers to dental care, leading to higher rates of untreated periodontal disease and tooth loss [14-16]. Therefore, while gender differences in tooth loss are evident, they are influenced by a complex interplay of individual behaviors, biological factors, and healthcare access, and may differ across different cultural and socioeconomic contexts. Results were mitigated concerning smoking and tooth loss, 12 studies showed that smokers had a higher tooth loss rate compared to non- or former smokers [14, 18–21, 23–25, 25–28]. Discrepancies in results between studies are probably due to different treatment modalities regenerative and non-regenerative and the fact that they included former smokers to the non-smoker group. Some of the articles included former smoker to the non-smokers group which can underestimate the long-term effects of smoking, as former smokers may still experience residual periodontal damage and this could be a reason for disagreement on the results. According to the literature, smoking cessation significantly benefits an individual's likelihood to decrease tooth loss, but it may take decades for the individual to return to the rate of tooth loss observed in non-smokers [20-23]. To have a satisfactory result after APT, patient cooperation should be achieved but is difficult to maintain. Therefore, further professional help is often needed. This is why the susceptibility of periodontitis is difficult to predict, and the treatment response could lead to disease recurrence and is also unpredictable. Consequently, patients need to engage in a supportive periodontal therapy which is evaluating periodontium, eliminating biofilm, reviewing radiographs if required, assessing oral hygiene, and retreating any sites with recurrence and updating medical and dental histories. The interval for maintenance visits varied among the studies due to the lack of a consensus report and the differing periodontal risks of patients. Typically, high-risk groups had more frequent visits, while low-risk groups had less frequent ones. Compliance, which measures how well a person's behavior aligns with medical advice, is influenced by factors related to both patients and providers. The literature reveals considerable variability in defining compliant individuals, with no consensus on case definitions. This could be the reason why we have heterogeneity in the results of the included studies concerning irregular and regular compliers and tooth loss rates [13-15, 18, 19, 21, 23–25, 28]. Studies on tooth type [13, 25, 29] and on furcation involvement [16, 17, 20, 23] found that furcally involved molars had a higher risk of tooth loss, followed by premolars then anteriors. Also maxillary teeth were found to be lost more than mandibular teeth [25]. Multi-rooted teeth are generally more susceptible to periodontal disease and present greater challenges during active and supportive periodontal therapy. Additionally, molars often present big restorations or endodontically treated, which may sometimes lead to their removal for reasons other than periodontal issues [13-29]. When assessing mobility, reported in 3 articles, all authors agreed that tooth mobility degrees II and III had a higher tooth loss than no mobility [16, 20, 29]. Mobility comes from weakened support structures, such as the periodontal ligaments and bone, often due to periodontal disease [29] which causes bone loss and inflammation, which compro-

mises the tooth's stability. Additionally, a mobile tooth can disrupt the bite, placing extra stress on surrounding teeth and exacerbating the problem, ultimately increasing the likelihood of tooth loss. In some of the included studies, the measurements of tooth mobility were further affected by the use of tooth splinting [20]. All three studies that examined this factor identified the presence of a root filling or apical lesion as a predictor of tooth loss [13, 20, 29] Generally, the loss of pulp vitality, along with the presence of a root canal filling or apical lesion, has been found to increase the risk of tooth loss, not just in patients with periodontitis.

This review has a number of strengths and limitations. The limitations include the heterogeneity of the studies regardless of primary inclusion and exclusion criteria for article selection for the present study. Also, differences in how data are reported and measured across studies could hinder accurate comparisons and synthesis of findings. This heterogeneity suggests a potential benefit from future conducting a meta-analysis, which could provide a more precise estimate of the effect size and help reconcile discrepancies among the study findings. Future research should aim to standardize definitions and measurement methods to improve comparability across studies. Large-scale, longitudinal studies that examine the combined effects of multiple risk factors over time are needed to better understand their impact on tooth loss.

Conclusion

This systematic review highlights variability in the literature regarding compliance, smoking, and recall intervals during supportive periodontal therapy (SPT), driven by differing classification models of these factors. Most studies identified older age, male gender, smoking, diabetes, irregular SPT attendance, and specific tooth-level factors (such as high probing depth, mobility, molars, and furcation involvement) as major modifiable risk factors for tooth loss. Tailoring periodontal maintenance programs to specific risk factors is crucial for optimizing patient outcomes and preventing tooth loss. By considering factors like age, smoking, oral hygiene habits, and tooth characteristics, clinicians can personalize care to better address the unique needs of each patient. However, due to significant study heterogeneity, the generalizability of these findings is limited. Clinicians should consider these factors with caution when making treatment decisions and use the insights from this review to guide clinical decision-making and improve patient management strategies in periodontitis care.

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