EFFECT OF SUPPORTIVE PERIODONTAL THERAPY ON TOOTH LOSS IN REGULAR AND IRREGULAR COMPLIANT SMOKERS AND NON-SMOKERS: A SYSTEMATIC REVIEW

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Aim: The aim of this systematic review is to analyze and compare tooth loss (TL) rates between regular and irregular compliant patients having different smoking habits.

Materials and Methods: Electronic and manual literature searches were conducted by one author in several databases, including Medline (PubMed), Embase, Google Scholar. A total of 156 publications were screened. Three reviewers analyzed the articles and extracted the data. A total of 33 studies met the inclusion criteria.

Results: A total of 30 articles were eligible for qualitative analysis, and only 3 for quantitative analysis. Compliance and smoking case definition as well as recall intervals during supportive periodontal therapy (SPT) differed widely between studies. A total of 10 publications reported significant differences in TL rates between regular (RC) and irregular compliant (IC) patients, while 25 publications reported significant differences in TL rates between smokers and non-smokers.

Conclusion: Regular attendance to SPT visits and non-smoking patients are associated with fewer TL rates. Smoking is considered a major modifiable risk factor for TL.

Key Words: Compliance, Maintenance, Smoking, Tooth loss

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

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EFFET DE LA THÉRAPIE PARODONTALE DE SOUTIEN SUR LA PERTE DE DENTS CHEZ LES FUMEURS RÉGULIERS ET IRRÉGULIERS ET CHEZ LES NON-FUMEURS: UNE REVUE SYSTÉMATIQUE

Objectifs : Le but de cette revue systématique est d'analyser et de comparer les taux de perte de dents (TL) entre des patients conformes régulièrement et irrégulièrement ayant des habitudes tabagiques différentes.

Matériels et méthodes: Des recherches documentaires électroniques et manuelles ont été effectuées par un auteur dans plusieurs bases de données, notamment Medline (PubMed), Embase et Google Scholar. Au total, 156 publications ont été examinées. Trois évaluateurs ont analysé les articles et extrait les données. Au total, 33 études répondaient aux critères d'inclusion.

Résultats: Au total, 30 articles étaient éligibles à l'analyse qualitative, et seulement 3 à l'analyse quantitative. La définition des cas d'observance et de tabagisme ainsi que les intervalles de rappel pendant le traitement parodontal de soutien (SPT) différaient considérablement d'une étude à l'autre. Au total, 10 publications ont signalé des différences significatives dans les taux de TL entre les patients réguliers (RC) et irréguliers (IC), tandis que 25 publications ont signalé des différences significatives dans les taux de TL entre les fumeurs et les non-fumeurs.

Conclusion: La participation régulière aux visites SPT et les patients non-fumeurs sont associés à moins de taux de TL. Le tabagisme est considéré comme un facteur de risque modifiable majeur de TL.

Mots clés: Conformité, entretien, tabagisme, perte de dents.

Introduction

Periodontal disease is a bacterial-induced inflammatory condition affecting the hard and soft tissue structures supporting the dentition. It encompasses a wide variety of inflammatory conditions that involve the gingiva, bone, and periodontal ligaments.

Periodontal disease is initiated with a localized or generalized inflammation of the gingiva termed "gingivitis". Its etiology is dental plaque, which is defined as a bacterial biofilm present on hard and soft tissues in the oral cavity. Gingivitis is detectable clinically by the presence of bleeding on probing (BOP), loss of stippling, and friability of gingival tissues [1]. If gingivitis is not cured, a chronic inflammatory condition may be initiated, which affects the alveolar bone and periodontal ligaments, termed "periodontitis". The initiation of periodontal pockets around teeth are the hallmark for periodontal disease progression. Periodontal pockets are abundant in dental plaque and bacterial metabolites which continuously deteriorate the periodontium. Periodontitis is characterized by irreversible hard and soft tissue destruction resulting in progressive attachment loss, and eventually leading to tooth loss (TL). It is detectable clinically by clinical attachment loss (CAL) using a periodontal probe with reference to the cementoenamel junction (CEJ) [2].

The 2018 workshop classification of periodontal and peri-implant diseases and conditions determined the threshold for BOP in periodontal healthy individuals, stating that gingival health encompasses no more than 10% BOP in the absence of attachment loss. Additionally, individuals with reduced but healthy periodontium, should have BOP <10% in the presence of attachment loss, with no probing depth greater than 3 mm [2].

According to a systematic review by Needleman in 2018, periodontitis is considered the sixth most prevalent disease of mankind with public health problems, since it is widely prevalent and causes disability, impaired quality of life, and social inequality. It is characterized clinically with mean annual attachment loss and TL of 0.1 mm and 0.2 teeth per year respectively, having variability within and between populations [3].

Even though no treatment modality is available to effectively cure periodontitis, precursor of gingivitis, can be managed and prevented by a thorough plaque and biofilm control, lifestyle changes, and decrease the effects of modifiable risk factors, such as smoking cessation and glycemic control [4]subsequently, to generate internally consistent prevalence and incidence estimates for all countries, 20 age groups, and both sexes for 1990 and 2010. The systematic search of the literature yielded 6,394 unique citations. After screening titles and abstracts, we excluded 5,881 citations as clearly not relevant to this systematic review, leaving 513 for full-text review. A further 441 publications were excluded following the validity assessment. A total of 72 studies, including 291,170 individuals aged 15 yr or older in 37 countries, were included in the metaregression based on modeling resources of the Global Burden of Disease 2010 Study. SP was the sixth-most prevalent condition in the world. Between 1990 and 2010, the global age-standardized prevalence of SP was static at 11.2% (95% uncertainty interval: 10.4%-11.9% in 1990 and 10.5%-12.0% in 2010. If gingivitis prevention was not performed, periodontitis could eventually develop, and professional treatment is required [5]. Active periodontal therapy (APT) is implemented to reduce the inflammatory reaction through eliminating bacterial deposits, either surgically or non-surgically, depending on the severity of the case [3]. The long-term effectiveness of APT relies on the maintenance of an ecosystem at the level of the gingival sulcus that must be compatible with the situation of a balanced host-parasite equilibrium. Such equilibrium mostly depends on daily elimination of bacterial plaque by the patient. Since patient cooperation is difficult to maintain long-term, professional help is mostly needed [6]is a major cause of tooth loss impacting negatively upon speech, nutrition, quality of life and self-esteem, and has systemic inflammatory consequences. Periodontitis is preventable and treatment leads to reduced rates of tooth loss and improved quality of life. However, successful treatment necessitates behaviour change in patients to address lifestyle risk factors (e.g. smoking).

The maintenance of a healthy periodontal condition is achieved by applying a supportive periodontal therapy program (SPT). SPT performed at selected time intervals aims to assist the maintenance of periodontal health [7]chronic inflammatory disease that destroys the connective tissues and bone that support teeth. Active periodontal treatment aims to reduce the inflammatory response, primarily through eradication of bacterial deposits. Following completion of treatment and arrest of inflammation, supportive periodontal therapy (SPT) . SPT should include all components of a typical dental recall examination, such as, periodontal evaluation, risk assessment, supra- and sub-gingival plaque and calculus removal, and lastly, retreatment of recurrent diseased sites. This results in monitoring the disease's condition and reducing or eliminating the etiological factors. If SPT is not properly delivered, progression of periodontal disease would occur despite completion of APT [8].

Several factors modify the outcome of SPT. Compliance is considered a critical factor for the maintenance of periodontal condition [9]. According to Haynes, compliance refers to the extent to which a person's behavior coincides with a medical or health advice [10]. Traditionally, patient compliance in periodontics includes self-care at home by means of toothbrushing and other oral hygiene regimens as well as

professional care at different time intervals. A classic problem faced during SPT is patient compliance [11]. A recent systematic review by Amerio et al. in 2019 demonstrated that the level of compliance with SPT is mostly unsatisfactory with high variability across studies. The highest drop of compliance seems to occur in the early years of SPT and tends to stabilize after. The rate of compliance across 39 studies included had great variability ranging between 3.3% and 86.8% [12]. The decreased rate of compliance would negatively affect the periodontal status, rendering an increased susceptibility of disease recurrence and eventually leading to TL.

On the other hand, risk factors are present and can modify the course of periodontal disease progression, one of these factors is tobacco smoking. It is considered a major modifiable risk factor, which negatively affects the progression of periodontal disease [13]. Smokers show faster disease progression and recurrence, worse periodontal status, negative response to periodontal treatment, experience greater TL rates, and are associated with low level of compliance compared to non-smokers [14]. Additionally, smokers show less gingival inflammatory status due to the vasoconstricting effect of nicotine. The actual immunoinflammatory mechanisms that could precisely explain the intensified severity and progression of periodontitis in tobacco users have not been completely elucidated yet. Nevertheless, it seems that oxidative stress and alterations in immunoinflammatory systems play important roles in the pathogenesis of smoking-related periodontitis. In vitro studies mostly agree that tobacco and its compounds present deleterious stimuli for the function of periodontal cells [15].

Teeth preservation is the primary goal of periodontal therapy. Success is measured by the declining rates of edentulism and an increase in the number of retained teeth. TL is the most visible result of periodontal disease evolution which negatively affects the patient's physiological and psychological aspect. There is a wide heterogenicity in annual TL rates after APT due to different techniques adopted during the active phase, SPT intervals, rate of periodontal disease, and study design [16]

To date, there is a void in the literature addressing the direct influence of compliance to arrest periodontitis progression and reducing TL rates, specifically in tobacco smoking patients. The aim of this systematic review is to determine TL rates in regular and irregular compliant individuals with different smoking habits.

Materials and Methods

This systematic analysis was performed according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement.

Eligibility criteria and study selection:

Articles aimed to determine TL rates in different compliant subjects, having data on different smoking habits during SPT were selected.

The included study designs were as follow:

- Randomized control trials.
- Cross-sectional.
- Cohort/case–control.
- Interventional studies.

The excluded articles were as follow:

- Systematic review.
- Narrative review.
- Presence of a more-recent follow-up publication including the same patient pool.
- Failure to report TL rates.
- Studies reporting about compliance with oral hygiene instructions only or with APT.
- Non-English articles.

Three reviewers (RK, AK, and NM) screened titles and abstracts. Studies selected by at least one reviewer were included in the full-text analysis. Any disagreement was solved by means of a discussion between the three reviewers after reading the entire manuscript, and if no agreement was reached the decision was made to include the article. References of the papers included in the full-text analysis were also examined to find other potential articles.

Literature search protocol:

Electronic and manual literature searches was conducted by one author (RK) in several databases, including Medline (PubMed), Embase, Google Scholar.

The PubMed database was searched for papers using the following strategy: ("periodontal maintenance therapy" OR "supportive periodontal therapy" OR "maintenance" OR "compliance" OR "compliant" OR "adherence" OR "maintenance care" OR "long-term care" OR "long-term maintenance") AND ("smoking*" OR "smoker" OR "smokers" OR "nicotine" OR "cigarette" OR "cigarette smoking" OR "tobacco" OR "tobacco smoker" OR "non-smoker" OR "non-smokers") AND ("tooth loss" OR "tooth loss rate" OR "tooth loss rates" OR "tooth mortality" OR "tooth morbidity" OR "dental mortality" OR "dental morbidity"). Only English articles were filtered.

In addition, the grey literature of unpublished data was searched using Open Grey databases. To complete the research, references of the included and excluded studies were also checked.

Data collection:

Data were independently extracted by three reviewers (RK, AK, and NM) in piloted forms focusing on the main outcomes of the systematic review (TL rates in different compliant patients, TL rates in smoking habits). Compliance case definition, smoking case definition, and variables related to TL were also extracted and recorded in an Excel sheet.

Methodological quality assessment:

The following criteria was used to classify the potential risk of bias for

each article, as applied in a previous review [17]:

- 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 and year of publication.
- Study design.
- Follow-up period.
- Sample size.
- Compliance definition.
- Compliance rate.
- Smoking status definition.
- TL rates/OR.

Data synthesis:

The present systematic review was divided into two parts:

-Qualitative assessment: separate TL rates for compliance and smoker/non-smoker patients.

-Quantitative assessment: results where both outcomes (smoking and compliance) were combined into one TL rate.

Results

Study selection:

The electronic search yielded 156 papers, and after titles and abstract screening, a total of 71 articles were selected for full-text analysis. Of these, 38 articles were excluded due to different reasons such as duplicates, no correlation between SPT and TL, no clear definition of compliance cases, and no mention of SPT recall interval. Hence, a total of 33 articles were included in this systematic review, 25 of which were retrospective cohorts [17–41], 5 were prospective cohorts [42–46] one of the most visible results of the evolution of periodontitis, causes physiological and psychological impacts on a patient's life. This prospective study aimed to evaluate the incidence, underlying reasons and influence of risk predictors for the occurrence of TL in a program of periodontal maintenance therapy (PMT, 1 was partially prospective in nature [47], 1 longitudinal study [48] the effect of cigarette smoking on the recurrence of disease in patients undergoing regular maintenance therapy is less understood. Therefore, we set out to assess disease progression longitudinally in smoking and non-smoking subjects with chronic periodontitis undergoing periodontal maintenance therapy every 3 to 4 months.\nMethods: A total of 108 subjects undergoing regular maintenance therapy for chronic periodontitis were followed over a 3-year period. Self-reports of smoking status were confirmed by analysis of exhaled carbon monoxide concentrations. Clinical parameters (plaque index [PI], bleeding on probing [BOP], clinical attachment loss [CAL], probing depth [PD], and tooth loss, and 1 case-control nested in a cohort study [49] (Figure 1).

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 of Quality Assessment of Selected Studies:

From the articles included in the present review, the quality evaluation showed that 6 studies presented low risk of bias, 17 studies presented with moderate risk of bias, and 16 studies presented with high risk of bias (Table 1).

Quantitative Analysis:

A Total of 3 [41,42,49] studies reported compliance status and smoking habit together in TL rates. Only 2 [42,49] out of 3 studies reported significant differences in TL rates between compliant non-smokers vs non-compliant non-smokers. The results of the quantitative analysis are summarized in table 2.

Costa et al. [49] in 2011 conducted a case-control cohort study to determine and compare periodontal status, especially progression of periodontitis and TL, among regular and erratic compliant smokers and non-smokers. A total of 116 patients, diagnosed with chronic moderate to advanced periodontitis, were randomly selected and followed for 3 years. During each SPT visit, PPD, clinical attachment level (CAL), BOP, and PI were recorded. Patients were classified as regular (RC) or erratic compliers (EC) according to the classification of Demirel and Efeodlu in 1995 [50]. The SPT recall interval for RC was 3.3 ± 0.5 months, while EC 8.1 ± 0.8 months. Self-reported smoking status was obtained from patients and classified according to Tomar and Asma in 2000 [51]. At the end of the follow-up period RC smokers, RC non-smokers, EC smokers, and EC non-smokers showed 2.93, 2.86, 3.49, and 3.33% TL respectively with significant differences between compliance and smoking status.

Costa et al. [42] in 2014 performed a prospective cohort study aimed to evaluate the incidence, underlying reasons, and influence of risk predictors for the occurrence of TL in different compliant patients for a period of 5 years. A total of 212 patients, diagnosed with chronic moderate to severe periodontitis were recruited into a SPT after active periodontal therapy (APT). Patient were categorized as regular compliant (RC) and irregular compliant (IC) according to the classification

of Renvert and Persson in 2004 [9]. Periodontal parameters, such as PI, PPD, CAL, BOP, furcation involvement, and TL were recorded at each SPT visit. Self-reported smoking status was recorded and classified according to Tomar and Asma [51]. During the entire follow-up period, RC had 11.2 ± 2.8 SPT visits, while IC had 5.4 ± 1.3 SPT visits. At the end of the 5-year period, TL percentages for RC smokers, RC non-smokers, IC smokers, and IC non-smokers were 17, 7, 32, and 8% respectively. Irregular compliance and smoking had a significant difference in TL rates with OR 3.13 and 4.22 respectively.

Huang et al. [41] in 2016 conducted a retrospective study to evaluate and compare periodontal status, compliance rates, and influence of risk factors on periodontal recurrence and TL in compliant and non-compliant (NC) patients. A total of 161 patients, affected by chronic or aggressive periodontitis, were randomly recruited, and followed for a mean period of 3.8 years with a SPT program having 6 months recall interval. Probing pocket depth (PPD), bleeding on probing (BOP), and plaque index (PI) were recorded at each SPT recall visit. Compliance was defined according to Mendoza et al. in 1991 [52]the patients were classified as either compliant or non-compliant. The results indicated that there were no significant differences between compliant and non-compliant patients with regards to age, sex, number of missing teeth, plaque score, or periodontal disease severity. More non-compliant patients than compliant patients were smokers (P less than 0.05, while the smoking status was not properly defined. Concerning the results of combined parameters, only odd ratio (OR) of TL was provided for both compliant and non-compliant groups. Regular compliant smoking patients had OR of 0.0 (0.00-10.7) with 95% CI while non-compliant smoking patients had OR of 2.8 (0.49-16.03) with 95% CI without significant differences.

Qualitative Analysis:

A total of 30 studies were included in the qualitative analysis, 8 of them reported significant difference in TL rates in different compliant patients [23,25,27,33,43,45–47]test for interleukin-1 (IL-1, while 23 reported significant difference in TL rates between different smoking habits [17–23,25–33,35–37,43–46]. The results of the qualitative analysis are summarized in table 3.

Retrospective Cohorts:

Eickholz et al. [23] in 2008 aimed to assess patient-related factors contributing to TL. A total of 100 patients (53 RC, 47 NC) completed the 10 year ± 6 months follow-up. Chronic moderate periodontitis was diagnosed in 30 patients, Chronic severe periodontitis in 60 patients, and aggressive periodontitis in 10 patients. SPT intervals were not performed according to a strict criterion. Most patients had 3-month intervals during the first year and later on in 6-month intervals. After 10 years of follow-up, RC and IC lost 0.55 ± 0.99 and 2.68 ± 4.44 respectively. Current smokers lost 2.22 ± 5.37, while former (> 5 years) and non-smokers lost 1.30 ± 2.06 teeth. Logistic regression analysis revealed OR of TL in IC and current smokers to be 4.715 and 1.389 respectively. Both IC and smokers were identified as risk factors for TL after 10 years.

Bäumer et al. [26] in 2011 evaluated patient-related risk factors contributing to TL and recurrence of periodontitis for 10.5 years. A total of 24 RC and 60 NC patients diagnosed with aggressive periodontitis were recruited. At the end of the follow-up, RC, NC, non-smokers, former-smoker, and smokers had tooth loss rates of 0.79 ± 1.18, 1.57 ± 2.74, 2.34 ± 3.42, 0.81 ± 1.25, and 0.82 ± 1.59 respectively. The relative risk for TL in former smoker, smokers, and NC was 0.79, 1.63, and 1.67 respectively. Statistical significance differences of TL were only found between smokers and non-smokers.

Ravidà et al. [36] in 2020 conducted a retrospective cohort to explore the effects of smoking on tooth loss due to periodontitis in long-term compliant patients. A total of 258 patients were enrolled in a SPT program (mean visits 2.24/year) for 10 to 47 years (mean 24.2 years). The smoking status was categorized as never-smokers, former smokers, current light smokers (<10 cigarettes/day), and current heavy smokers (≥10 cigarettes/day). Out of 6,590 teeth present at baseline, 64 teeth were lost due to periodontitis, corresponding to 0.03, 0.05, 0.08, and 0.11 TLP annually among never-smokers, former-smokers, current light-smokers, and current heavy-smokers, respectively. Additionally, the risk for tooth loss from a current heavy smoker had 4.4-fold, 2.7-fold, and 2.6-fold greater risk of TLP than a tooth from a never-smoker, a current light-smoker, and a former-smoker, respectively. Lastly, it took almost 15 years of smoking cessation for the risk of TLP among former smokers to reach the level of never-smokers.

Junge et al. [38] in 2021 assessed tooth loss in initially periodontally healthy/gingivitis (PHG) and periodontally compromised (PC) patients for a period of 15 to 25 years (mean 20 years). PC patients were affected with at least stage II periodontitis. All 107 patients in both groups (56 PC, 51 PHG) were classified as regular compliers with an average of 2.34 ± 0.56 and 1.58 ± 0.49 visits per year respectively. At the end of the follow-up, 0.03 ± 0.05 teeth/year and 0.04 ± 0.05 teeth/year were lost in PC and PHG respectively, with no statistical significance. Incidence risk ratio (IRR) of TL in active smokers was determined to be 0.549. It should be noted that both PC and PHG groups were heterogenous in nature and the number of non-smokers among PHG (69%) was fewer than among PC (91%).

Prospective Cohorts:

The association of periodontal risk assessment (PRA) model with the recurrence of periodontitis and TL during SPT was assessed by Costa et al. [44] in 2012. A total of 75 RC and 89 EC patients completed the follow-up period of 3 years. All patients were diagnosed with chronic moderate to advanced periodontitis. PRA was performed in the first and last SPT visit, risk profiles were evaluated, and TL was recorded. A maximum 4-month interval was proposed for all patients, independent of their risk profiles. At the end of the follow-up, RC showed less recurrence of periodontitis and TI rates than EC, with statistical significance. RC and EC were presented with 0.65 ± 1.4 and 0.78 ± 2.1, respectively. The multivariate logistic regression model revealed OR for TL in RC vs EC and smokers vs non-smokers to be 2.35 and 3.41 respectively, with statistical significant differences.

Ravald and Johansson [45] in 2012 assessed periodontal conditions, root caries, number of lost teeth and causes for TL during 11–14 years of SPT after APT. Periodontal examination was conducted at baseline and at each SPT visit, including periodontal pocket depth (PPD), plaque index (PI), BOP, furcation involvement (FI), and reasons of TL. A total of 64 patients completed the follow-up, classified as 45 RC (1-4 SPT visits per year) and 19 IC (1-2 SPT visits per year). TL rates for each group were not calculated, but stepwise logistic regression analysis showed that smoking OR 8.0 (1.6–39.0) as well as the number of SPT visits statistically contributed to increased TL rates.

Albuquerque et al. [46]as well as tooth loss, in individuals under PMT in a public/academic environment. Materials and methods: From a PMT program at a public university, 39 individuals determined to be regular compliers (RC in 2018 evaluated periodontal retreatment needs, progression of periodontitis, and TL, in individuals under SPT in a public/academic environment. A total of 91 recruiters had undergone non-surgical and/or surgical procedures followed for 6.5 years. Periodontal examinations were conducted at each SPT visit to evaluate PPD, CA loss and BOP. At the end of the follow-up, 39 and 52 patients were classified as RC and IC respectively, according to Renvert and Persson [9]. RC and IC were presented with 4.5 ± 0.2 and 8.2 ± 0.8 TL rates respectively, with statistically significant differences. When using univariate and multivariate logistic regression models, smoking did not reach a statistical significance.

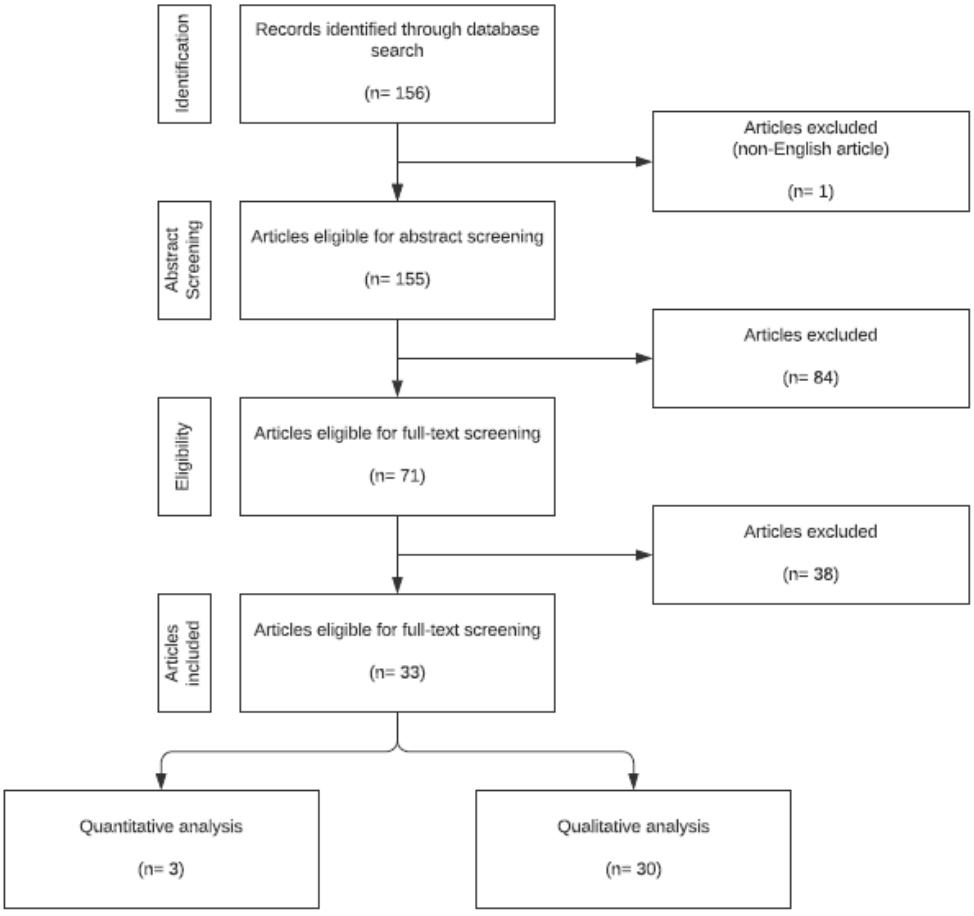

Figure 1. Literature search flow chart.

Table 1: Quality assessment of selected studies.

Author and Year	Random selection in population	Defined inclusion/exclusion criteria	Reported loss to follow up	Validated measurements	Statistical analysis	Estimated potential risk of bias
McGuire and Nunn 1996	No	No	No	Yes	No	High
Tonetti et al. 1998	Yes	Yes	No	Yes	Yes	Moderate
König et al. 2002	No	No	No	Yes	Yes	High
Fardal et al. 2004	No	Yes	No	Yes	No	High
Rieder et al. 2004	No	No	No	Yes	Yes	High
Chambrone and Chambrone 2006	No	Yes	No	Yes	No	High
Eickholz et al. 2008	No	Yes	Yes	Yes	Yes	Moderate
Fisher et al. 2008	Yes	Yes	Yes	Yes	Yes	Low
Matuliene et al.2008	No	Yes	Yes	No	Yes	High
Tsami et al. 2009	No	Yes	No	Yes	Yes	High
Bäumer et al. 2011	No	Yes	Yes	Yes	Yes	Moderate
Costa et al. 2011	Yes	Yes	No	Yes	Yes	Moderate
Costa et al. 2011	Yes	Yes	Yes	Yes	Yes	Low
Costa et al. 2012	No	Yes	Yes	Yes	Yes	Moderate
Ravald and Johansson 2012	No	Yes	Yes	Yes	Yes	Moderate
Costa el al. 2014	No	Yes	No	Yes	Yes	High
Salvi et al. 2014	No	No	Yes	Yes	Yes	High
Dannewitz et al. 2016	No	Yes	No	No	Yes	High
Graetz et al. 2016	Yes	Yes	No	Yes	Yes	Moderate
Huang et al. 2016	Yes	No	No	Yes	Yes	High
Díaz-Faes et al. 2017	Yes	Yes	Yes	Yes	Yes	Low
Gratez et al. 2017	Yes	Yes	No	Yes	Yes	Moderate
Martinez-Canut et al. 2017	Yes	Yes	No	Yes	Yes	Moderate
Albuquerque et al. 2018	No	Yes	No	Yes	Yes	High
Pretzl et al. 2018	Yes	Yes	Yes	Yes	Yes	Low
Hirata et al. 2019	No	Yes	Yes	No	Yes	High

Bäumer et al. 2020	No	Yes	Yes	Yes	Yes	Moderate
Kawahara et al. 2020	No	Yes	No	Yes	Yes	High
Petsos et al. 2020	No	Yes	Yes	Yes	Yes	Moderate
Rahim-Wöstefeld et al. 2020	No	Yes	Yes	Yes	Yes	Moderate
Ravidà et al. 2020	Yes	Yes	Yes	Yes	Yes	Low
Farina et al. 2021	Yes	Yes	No	Yes	Yes	Moderate
Junge et al. 2021	Yes	Yes	Yes	Yes	Yes	Low

Table 2: Study characteristics of included studies in the quantitative analysis. RC: regular compliant, EC: erratic compliant, IC: irregular compliant, NS: non-smoker, FS: former smokers, S: smoker, Y: years, M: months, OR: odds ratio, NA: not available, *: significant difference on TL in different smoking habits, #: significant difference on TL in different compliance patients.

Author and Year	Design	Sample Size	Follow-up	TL Rates	OR	SPT interval	Compliance Definition	Smoking Definition
Costa et al. 2011*#	Case-Control Cohort	116 RC + NS: 38 RC + S: 20 EC + NS: 38 EC + S: 20	3 Y	RC + S: 14 ± 2.93 RC + NS: 26 ± 2.86 EC + S: 16 ± 3.49 EC + NS: 29 ± 3.33	RC + S: 4.2 (1.42-9.89) EC + S: 7.3 (1.17-14.9)	RC: 3.3 ± 0.5M EC: 8.1 ± 0.8M	RC: Adhered to the suggested SPT intervals (max delay 1M). EC: Not adhering to the scheduled SPT intervals.	S/FS: Smoked >100 cigarettes throughout their lives. Non-smoker: Never smoked in their entire lives.
Costa et al. 2014*#	Prospective Cohort	212 RC + NS: 71 RC + S: 25 IC + NS: 83 IC + S: 33	5 Y	RC + S: 17% RC + NS: 7% IC + S: 32% IC + NS: 8%	S: 4.22 (2.01-12.78 IC: 3.13 (1.45-4.98	Number of SPT visits: RC: 11.7 ± 2.8 IC: 5.4 ± 1.3	RC: 100% compliant for SPT visits, with a maximum interval of 6M between recalls. IC: Missed any of the SPT visits, but continued to appear on an irregular basis, with a maximum interval of 18M between recalls.	S/FS: Smoked >100 cigarettes throughout their lives. NS: Never smoked in their entire lives.
Huang et al. 2016	Retrospective Cohort	161 RC + NS: 89 RC + S: 5 NC + NS: 50 NC + S: 17	3.8 Y	NA	RC + S: 0 (0.0-10.7) NC + S: 2.8 (0.49-16.03)	6 M	RC: 100% compliant with suggested SPT. NC: Missed 2 or more appointments but were still attending for treatment.	NA

Table 3: Study characteristics of included studies in the qualitative analysis. FC: full compliant, RC: regular compliant, EC: erratic compliant, C: compliant, IC: irregular compliant, O: optimal, SO: sub-optimal, NS: non-smoker, FS: former smokers, S: smoker, LS: light smoker, OS: occasional smoker, MS: moderate smoker, HS: heavy smokers Y: years, M: months, OR: odds ratio, RR: relative risk, HR: hazard ratio, NA: not available, *: significant difference on TL in different smoking habits, #: significant difference on TL in different compliance patients.

Author and Year	Design	Sample Size	Follow-up	TL Rates	OR	SPT interval	Compliance Definition	Smoking Definition
Mc Guire and Nunn 1996*	Retrospective Cohort	100 RC: 100	9.97 Y	RC: 23.66% S: 62.6%	RR: 2.059	2–3-month intervals	NA	NA
Tonetti et al. 1998*	Retrospective Longitudinal Survey	273 RC: 273 NS: 88 FS: 76	5.5 ± 3.8 Y	0.28 ± 0.64 teeth/ year	NA	3-month intervals	NA	NA
König et al. 2002*	Retrospective Cohort	142 RC: 142	11.7 ± 1.4 Y	0.07 teeth/ year	NA	NA	NA	NA
Fardal et al. 2004*	Retrospective Cohort	100 FC: 63 RC: 27 S: 26 NS: 74	9.82 ± 0.7 Y	FC: 0.41 teeth/ year RC: 0.27 teeth/ year S: 0.58 teeth/ year NS: 0.29 teeth/ year	RC: 0.37 (0.11–1.23) Smoker: 4.18 (1.27–13.79)	1-3 times per year	FC: 2 times/year RC: 1 time/year	NA
Rieder et al. 2004*	Retrospective Cohort	87 FC: 24 RC: 24 EC: 20 NC: 19	7.3 ± 1.5 Y	FC: 0.11 RC: 0.14 EC: 0.11 NC: 0.17 NS: 0.12 ± 0.20 OS: 0.18 ± 0.14 MS: 0.16 ± 0.14 HS: 0.13 ± 0.19	NA	3-9-months intervals	FC: Complied with the recommended recall interval within a week of the scheduled appointment. RC: Complied with the recommended recall interval within 1–3 weeks of the scheduled appointment. EC: Complied with the recommended recall interval within 3–6 weeks of the scheduled appointment. NC: Delayed their acceptance of the invitation to a recall visit by more than 6 weeks	NS: Never smoked OS: 1–9 cigs. /day MS: 10–19 cigs. /day HS: at least 20 cigs. /day

Chambrone and Chambrone 2006*	Retrospective Cohort	120 RC: 54 EC: 68 NS: 100 S: 20	17.4 Y	RC: 12.9% E: 20.6% S: 65.0% NS: 8.0%	S: 4.76 (1.42–15.89)	6-12-months intervals	RC: 6 months interval EC: 12 months interval	NA
Eickholz et al. 2008*#	Retrospective Cohort	100 RC: 53 NC: 47 NS: 73 S: 27	10 ± 0.5 Y	RC: 0.55 ± 0.99 NC: 2.68 ± 4.44 S: 2.22 ± 5.37 NS: 1.30 ± 2.06	IC: 4.715 S: 1.389	3-6-months intervals	NC: Extended the recommended SPT interval at least once over 100%	NA
Fisher et al. 2008	Longitudinal	108 RC:108 NS: 46 FS: 36 S: 26	3 Y	S: 8 NS: 8	NA	3-4-months intervals		Analysis of expired-air CO concentration. NS: <8 CO S: >8 CO
Matuliene et al. 2008	Retrospective Cohort	168 FC: 58 RC: 82 EC: 20 C: 7 NC: 1 NS: 62 FS: 60 LS: 13 MS: 12 HS: 21	11.3 ± 4.9 Y	1.71 teeth/ patient	LS: 1.4 (0.7–2.9) MS: 1.4 (0.7–2.9) HS: 1.2 (0.5–2.7)	NA	FC: Attending 3-4/year RC: Attending 2/ year EC: Attending 1/ year C: Attending <1/ year NC: Attending 0/ year	NS: Never smoked LS: 1-9 cigs. / day MS: 10-19 cigs. /day HS: at least 20 cigs. /day
Tsami et al. 2009*#	Retrospective Cohort	280 RC: 148 EC: 132 NS: 95 LS: 87 MS: 66 HS: 32	10.84 ± 2.13 Y	NS: 19.17% LS: 30.39% MS: 27.89% HS: 22.55%	NA	NA	RC: > 75% of the scheduled maintenance appointments EC: > 40% >75% of the scheduled maintenance appointments	NS: Never smoked LS: 1-9 cigs. / day MS: 10-19 cigs. /day HS: at least 20 cigs. /day
Bäumer et al. 2011*	Prospective Cohort	84 RC: 24 NC: 60 NS: 34 FS: 21 S: 29	10.5Y	RC: 0.79 ± 1.18 NC: 1.57 ± 2.74 S: 2.34 ± 3.42 FS: 0.81 ± 1.25 NS: 0.82 ± 1.59	RR: NS: 1 FS: 0.79 S: 1.63 NC: 1.67	NA	NC: extended the recall interval once over 100%	never/former [i.e. quit>5 years ago]/ current smoker

Costa et al. 2012*	Prospective Cohort	288 RC: 194 EC: 94 NS: 159 S/FS: 129	1 Y	NA	S: 3.1 (1.98-11.6)	108 ± 9.8 days	RC: 100% of cooperation with recall visits.	NS: Never smoked S/FS: smoked >100 cigarettes throughout their lives
Costa et al. 2012*#	Prospective Cohort	164 RC: 75 EC: 89 NS: 101 S: 63	3 Y	RC: 0.65 ± 1.4 EC: 0.78 ± 2.1	RC vs EC: 2.35 (1.02 - 5.23) S vs NS: 3.41 (1.26 - 11.41)	RC: 3.3 ± 0.5 M EC: 8.1 ± 1.2 M	RC: presented 100% cooperation with recall visits. EC: missed any of the scheduled recall visits but continued to appear irregularly.	NS/ex-smokers. S: 10 to 19 or >19 cigs. /day
Ravald and Johansson 2012*#	Prospective Cohort	64 RC: 45 NC: 19: NS: 46 LS: 7 HS: 11	12.5 Y	NA	S: 8 (1.6-39)	1-4 times a year	NA	NA
Salvi et al. 2014*#	Retrospective Cohort	199 RC: 199 NS: 40 S: 54	11.5 ± 5.2 Y	NA	RC: 1 NC: 2.26 (1.09-4.69) NS: 1 FS: 0.89 (0.49-1.64) S: 1.71 (1.02-2.84)	NA	RC: adhered to the suggested SPT intervals (max delay 1M). NC: not adhering to the scheduled SPT intervals.	NA
Graetz et al. 2014*	Retrospective Cohort	315 RC: 315 NS: 209 FS: 75 S: 31	18.2 ± 5.5 Y	RC: 0.15 / pat/year	HR: S: 2.62 (1.34-5.14) FS: 1.02 (0.59-1.76)	3-12-months intervals	NC: violated the recommended SPT-interval at least once by >100 %	NS/FS: quit >5 years ago

Dannewitz et al. 2016*	Retrospective Cohort	132 RC: 76 NC: 60 NS: 65 FS: 60 S: 11	13.2 ± 2.8Y	NA	HR: NC: 1.18 (0.68-2.05) S: 1.97 (1.05-3.68)	1.83±0.54 mean SPT interval	RC: attended at least one SPT appointment per year	S: more than 10 cigs. /day FS: quit smoking at least 5 years ago NS: patients who smoked up to 10 cigarettes/day or had never smoked
Graetz et al. 2017*	Retrospective Cohort	57 RC: 57 NS: 17 FS: 11 S: 29	17.4 ± 4.8 Y	RC: 0.14 ± 0.18/ pat/year	HR: FS: 3.22 (0.68-2.05) S: 1.00 (1.05-3.68)	3-12-months intervals	NA	S: more than 10 cigs. /day FS: quit smoking at least 5 years ago NS: patients who smoked up to 10 cigarettes/day or had never smoked
Díaz-Faes et al. 2017*	Retrospective Cohort	25 RC: 7 NC: 18 NS: 12 FS: 2 LS: 3 MS: 4 HS: 4	10.9 ± 2 Y	RC: 1.1 ± 0.6 NC: 1.5 ± 0.8 NS: 0.08 ± 0.29 S: 1.62 ± 2.57	β±se RC: 0.37 ± 0.90 S: 1.53 ± 0.75	4-6-months intervals	Compliant: attended all SPT appointments during the entire observation period	NS: never smoked FS: quit > 5 years LS: 1-9 cigs. / day MS: 10-19 cigs. /day HS: at least 20 cigs. /day
Martinez-Canut et al. 2017*	Retrospective Cohort	174 RC: 174 NS: 111 S: 63	20.2 ± 2.4 Y	S: 1.63 ± 1.63	NA	4-months intervals	NA	NS: never smoked, quit > 5 years S: > 10 cigs. /day
Pretzl et al. 2018*#	Retrospective Cohort	70 RC: 30 NC: 40 NS: 34 FS: 25 S: 11	20 Y	NA	RR: RC: 0.301 (0.207-0.432) FS: 1.346 (0.969-1.869) S: 4.169 (2.592-6.712)	AgP: 3-months intervals. CP: 3 months intervals during the first year and later on 6-month intervals.	NC: extended the recommended SPT interval at least once over 100%.	NS: never smoked FS: quit > 5 years S: smoker

Albuquerque et al. 2018*#	Prospective Cohort	150 RC: 39 NC: 52 NS: 31 FS: 47 S: 13	6.5 Y	RC: 4.5 ± 0.2 0.17 /pat/ year IC: 8.2 ± 0.8 0.29 /pat/ year NS: 51.9% FS: 30.8% S: 17.3%		RC: 6.2 ± 0.6 months IC: 13.1 ± 1.9 months	RC: Intervals between PMT visits were < 7 months IC: Intervals were > 7 and < 15 months	Tomar and Asma, 2000
Hirata et al. 2019	Retrospective Multicenter Cohort	82 RC: 82 NS: 62 S: 20	4.9 Y	NS: 0.0365 S: 0.0491	HR: NS: 1.0 S: 1.41 (0.49–4.09)	NA	NA	NA
Rahim-Wöstefeld et al. 2020#	Partially Prospective Cohort	69 NS: 31 FS: 27 S: 11	20 Y	Irregular: 17.6% Adherent: 6% S: 15.9% NS: 11.5%	Adherent 0.371 (0.08-0.492)	Assigned according to the periodontal risk assessment	Non-adherent: patient once exceeded the interval determined during SPT by more than 100%.	NA
Kawahara et al. 2020	Retrospective Cohort	674 RC: 636 NC: 38 NS: 548 S: 126	9.3 Y	RC: 0.09/pat/ year IC: 0.15/pat/ year NS: 0.09/pat/ year S: 0.09/pat/ year	RC: 1 IC: 1.89 (0.97-3.66) S: 0.92 (0.62-1.36) NS: 1	PPD ≥4 mm: 3-month intervals PPD <4 mm: 6-month intervals	RC: ≥70% of expected maintenance visits; and interval between visits during did not exceed a maximum of 2 years. IC: criteria for RC were not met but continued maintenance visits were carried out.	NA
Bäumer et al. 2020*	Retrospective Cohort	100 RC: 33 IC: 67 NS: 45 FS: 40 S: 15	25.5 ± 6.5 Y	RC: 1.18 ± 1.70 IC: 2.79 ± 4.08 NS: 1.40 ± 2.82 FS: 2.90 ± 3.75 S: 3.13 ± 4.58	HR: IC: 1.354 (0.296-1.354) S: 7.520 (1.051-7.520)	At least two visits per year	IC: extended the recall interval once over 100%	S: more than 10 cigs. /day FS: quit smoking at least 5 years ago NS: patients who smoked up to 10 cigarettes/day or had never smoked

Ravidà et al. 2020*	Retrospective Cohort	258 RC: 258 NS: 146 FS: 50 LS: 37 HS: 25	24.2 ± 6.7 Y	NS: 0.03 ± 0.06 /pat/ year FS: 0.05 ± 0.07 /pat/ year LS: 0.08 ± 0.19 /pat/ year HS: 0.11 ± 0.08 /pat/ year	NA	2.24 visits/ year	At least one PMT visit per year	LS: smoked <10 cigs. /day HS: smoked ≥10 cigs. /day
Petsos et al. 2020*#	Retrospective Cohort	100 RC: 58 NC: 42 NS: 53 FS: 38 S: 9	10 Y	Adherent: 0.52 ± 1.01 Non-adherent: 0.31 ± 0.72 NS/FS: 0.38 ± 0.79 S: 0.88 ± 1.69	RR: Non-adherent 2.804 S: 28.604	High periodontal risk: 4 times a year Low periodontal risk: 2 times a year	Non-adherent: patient once exceeded the interval determined during SPT by more than 100%.	NS: never smoked FS: quit smoking > 5 years ago S: stopped smoking < 5 years ago or currently smoking
Junge et al. 2021	Retrospective Cohort	107 RC: 107 NS: 86 FS: 14 S: 6	20.1 Y	NA	IRR: S: 0.549 (0.251 1.203)	AgP and severe ChP: 2/year Others: 1/ year	NA	NA
Farina et al. 2021	Retrospective Cohort	183 RC: 150 IC: 33 NS: 94 FS: 21 LS: 18 MS: 26 HS: 9	3.5 Y	RC: 0.14 NC: 0.21	NA	RC: 3.3 ± 0.5 months NC: 6.3 ± 1.5 months	RC: mean interval between SPT sessions fell within the range of 2–4 months NC: mean interval between SPT sessions > 4 months	NA

Discussion

The aim of this systematic review was to analyze and compare TL rates in different compliant patients with different smoking habits. Literature review search revealed wide heterogenicity between studies in terms of compliance definition, smoking habit classification, and study design. All patients included in the studies were affected by a degree of periodontal disease, treated surgically and/or non-surgically, and then enrolled in a maintenance program.

The long-term effect of APT depends on maintaining the ecosystem at the gingival sulcus, it should be compatible with a balanced host-parasite equilibrium. This balance is dependent on the daily elimination of plaque by the patients. Unfortunately, patient cooperation is difficult to maintain. Therefore, professional help is needed. Consequently, the susceptibility of periodontal disease is difficult to predict, and the treatment response is also unpredictable. Additionally, patients with a history of periodontal disease are at increased risk of disease recurrence. Therefore, patients must follow a routinely monitored program aimed to stabilize the periodontium, called SPT. In general, SPT appointments should include update of medical and dental history, periodontal and implant evaluation, biofilm elimination, radiographic review if needed, oral hygiene assessment, and re-treatment of recurrent sites. This will ensure the disruption of microbial colonies and minimize the inflammatory state. SPT therefore offers an opportunity for clinicians to promote

periodontal health, rapidly detect and intercept recurrence and progression of periodontal disease [7].

Compliance refers to the extent to which a person's behavior coincides with medical or health advice. It is determined by factors related to both the patient and the provider. According to the literature, there is a high degree of heterogenicity related to the definition of different compliant individuals, with no agreement regarding case definition of different compliant groups. In general compliance is classified into "regular compliant" where patients regularly attend their SPT visits, "erratic compliant" where patients tend to miss some of their SPT visits but are continued to show, and "irregular compliant" where patients failed to show to their SPT visits [11].

The maintenance visit interval was not homogenous among the included studies, due to the fact that no consensus report is available and different patients present with different periodontal risks. In general, high-risk groups were recalled at shorter intervals, while low risk groups were seen at a longer interval. In the present systematic review, RC patients in included studies were seen every 3 months while IC were recalled every 6 months. The recall interval is defined as the difference in time between two consecutive SPT visits. Most studies rely on a recall of 3 to 4 months, due to the fact that early studies showed a relative periodontal stability under such frequency. On the other hand, when SPT was provided only twice per year, periodontal stability was also achieved for a period over 14 years. Unfortunately, none of these studies provided a relationship between the amount of attachment loss and frequency of periodontal maintenance [11]

Early studies performed by Rosén et al. in 1999 aimed to determine the effect of different recall frequencies of SPT in relation to PD and CAL for a period of 5 years. Patients were appointed with periodontal maintenance at 3, 6, 12, and 18-month intervals. 84% of patients showed disease progression and the analysis failed to demonstrate differences between different recall intervals. This trial concluded that recall intervals at least once per year may be acceptable for periodontal patients [53]. Later on, Ramseier et al. in 2019 addressed this problem and conducted a retrospective study where they evaluated the time between recall visits and residual PPD in periodontal patients enrolled in a SPT for an average of 25.7 years. A total of 883 patients with 11,842 SPT visits were analyzed. Results show that patients returning for SPT earlier than anticipated presented mean % PPDs ≥ 4mm of 5.8% ± 3.9, while patients returning later than anticipated showed 19.2% ± 7.6. Moreover, patients attending > 50% of their SPT visits earlier versus later showed greater stability and decrease in TL rates 0.60 ± 0.93 versus 1.45 ± 2.07 respectively, after 20 years of SPT [54].

Farooqi et al. [55] in 2015 conducted systematic review to evaluate the evidence regarding the most appropriate time interval for SPT in patients previously treated for chronic periodontitis. Because no randomized controlled trials (RCT) or cohort studies directly comparing different time intervals between SPT visits could be found, the effect of patient compliance with the suggested SPT regimen on tooth retention was analyzed. Although more frequent SPT recall visits were associated with fewer TL in some studies, other reports showed no statistically significant differences in TL in cohorts with SPT intervals of less than or more than 6 months. The review concluded that "there is weak evidence to support a fixed and specific periodontal maintenance recall interval or evidence of a threshold interval after which TL is significantly higher. Limited evidence appears to favor more frequent periodontal maintenance recall visits, and the optimum frequency is "unclear" and a "one size fits all" type of recommendation seems to be questionable.

Although SPT is aimed to stabilize the periodontal condition, this goal is only achieved with patient's compliance. Unfortunately, low rates of compliance were found in the literature with a wide range of 11 to 88%, according to a systematic review by Lee et al. in 2015 [8]. Only a Norwegian study, conducted in a private clinic with a 10-year follow-up, achieved a high compliance rate of 87% [20]. Recently, Amerio et al. [12] in 2020 conducted a systematic review to address this issue, where they identified patient-related factors that could play a role on patient compliance. A total of 39 articles were included in the review. In 7 out of 9 studies, smoking was reported to be associated with low levels of compliance. Different explanations might support this finding. First, smokers may avoid SPT visits to prevent being constantly reminded of quitting smoking as well as the debilitating effect of smoking habit. Second, the blindness of the smoking patient to his/her general health could also explain the non-compliance nature. On the other hand, 3 studies showed that patients having a history of periodontal disease and patients having dental implant were more compliant. This is due to the fact that these patients have already invested time and money in their treatment and were likely to comply with their SPT visits.

In order to determine the reason behind non-compliance, 8 studies provided questionnaires for non-compliant patients to address this issue. Interestingly, it was found that inadequate information/motivation was the main reason for non-compliance, and this motive was three times more important that other reasons such as bad experience, dissatisfaction, or economic issues [12]. It has been shown that motivational interview and general education to be effective in improving general health as well as compliance rates in a systematic review. Additionally, providing insights about the importance of behavior change and seriousness of periodontal disease was found to be a predictor of behavioral change [56] yet little is known about its effects

during the formation of this biofilm. The present investigation was undertaken to examine the contributions of smoking to the composition and proinflammatory characteristics of the biofilm during de novo plaque formation. Marginal and subgingival plaque and gingival crevicular fluid samples were collected from 15 current smokers and from 15 individuals who had never smoked (non-smokers. Additionally, patients seem to ignore verbal instructions by the dentist to return for recalls. Postcards written in the patient's own handwriting or email reminders could be more effective to increase patient's compliance [41].

Very few studies reported TL rates with the combined parameters of compliance and smoking habit. Only 3 studies were eligible for the quantitative analysis. Moreover, 2 studies reported statistical significance in TL rates between RC and IC smokers and non-smokers [42,49]. Huang et al. [41] reported shallower PPD, less BOP and improved PI in both groups, but TL rates did not reach a statistical significance. This could be attributed to different compliance classification, and different extraction strategies between studies. Miyamoto et al. in 2006 reported that patients who attended at least 70% of 3 to 4 monthly SPT visits were significantly more likely to lose teeth than those attending less than 70% of visits. This could be attributed to the fact that patients who are highly compliant to the recommended SPT are also likely to have a more severely diseased condition and a higher rate of acceptance with regard to the proposed dental treatment [57]. On the other hand, one may speculate that if the extraction strategy was conservative during APT, i.e., retaining teeth with poor prognosis in an attempt to save them, then TL rates would likely increase during SPT if these teeth were not saved and vice versa [58]. Huang et al. [41] in 2016 reported increased periodontal recurrence in smoker patients but without increase in TL rates. This could be explained by the fact that most of the patients affected by periodontal recurrence were regularly followed and treated before reaching the end stage of periodontal disease.

A total of 25 studies reported significant TL rates between smokers and non-smokers. There are several mechanisms that explain the interaction between smoking and periodontal disease and reduced healing observed in smokers. To date, no clear evidence is present for a particular mechanism as being of greater importance, but rather a combination of several mechanisms [59]. Such mechanisms include a shift toward more pathogenic flora, decrease in microcirculation, neutrophils dysfunction, overproduction of proinflammatory cytokines, increase levels of pathogenic T-cells, and inhibition of fibroblast proliferation [60]. The shift toward a more pathogenic microbiome, by increasing the magnitude of periodontal pathogens, such as P. gingivalis, T. denticola and T. forsythia, was proposed to increase the incidence and progression of periodontal disease in smokers compared to non-smokers [61]. Another mechanism of action is the peripheral vasoconstriction due to nicotine consumption. This leads to compromised microvascular response, which eventually leads to reduced oxygen tension in periodontal pockets, thus favoring the overgrowth of anaerobic pathogens such as P. gingivalis and T. denticola [62]. It is critical to note that acute and chronic exposure to tobacco have different effects on the immunoinflammatory system. Acute exposure occurs when the subject is smoking, it generates high concentration of tobacco products in tissues and fluids, whereas chronic exposure occurs after smoking, which provides low but consistent release of tobacco products [63].

Lastly, only 10 studies reported significant differences in TL rates between RC and IC patients, while the rest of the studies either did not report TL rates, sampled only compliant patients, or results did not reach a statistical difference. This could be attributed to the fact that time intervals for recall during SPT varied significantly between studies, different surgical procedures during APT, difference in periodontal procedures performed during SPT, and evaluation of different periodontal parameters. On the other hand, compliance case definition and criteria to classify regular and irregular patients were heterogenous among included studies. This could affect different periodontal and TL outcomes.

Recommendations for Future Research

Methodological standardization for the following issues is imperative:

- Consensus report for recall intervals during SPT.
- Identification of unique dental care protocols and periodontal procedures performed during SPT.
- Characterization of compliance case definition and using standardized compliance classification.
- Characterization of smoking status in terms of both frequency and dose-exposure.
- Studies with larger samples and longer follow-up periods that include both parameters (compliance and smoking) in TL rates are necessary.

Conclusion

The present systematic review revealed wide heterogenicity in literature concerning compliance case definition, smoking habit classification, and different recall intervals during SPT. Nonetheless, most of the included studies showed that RC patients presented with fewer TL rates compared to IC ones, even if statistical significance was not reached. Most of the included studies showed a positive relation between smoking and increased TL rates. Smoking is considered a major modifiable risk factor in periodontal disease, leading to TL if not managed properly.

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