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A Novel System for Predicting Periodontal Outcomes: Analysis of the 2017 Periodontitis Classification based on a Systematic Review

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Abstract

This study assesses the 2017 Classification of Periodontitis from a prognostic perspective, extending beyond mere tooth loss. Through a systematic review, we compare this classification to previous major systems, examining their prognostic capabilities. Additionally, we introduce a new, simpler, and more efficient prognostic system.

A total of 89 articles were selected from database searches, and a color gradient scale was utilized to compare the 2017 classification with earlier prognostic systems.

The prognostic capability of the 2017 classification is comparable to McGuire's system, with various stages and grades aligning with different prognostic outcomes. We propose a novel periodontal prognostic scale (PPS) system based on 12 parameters.

In conclusion, the 2017 classification offers both diagnostic and limited prognostic capacities for assessing periodontitis. Visual comparisons with major prognostic systems indicate its potential for estimating periodontal prognosis, with the best match found in Kwok and Caton's system. The introduction of the new PPS system emphasizes convenience and simplicity, with plans for verification and updates in future studies.

Keywords: Periodontitis, Prognosis, Periodontal Risk Factors, Risk Factor, Systematic Review/Meta-analysis

Introduction

Risk and prognostic factors are critical considerations for clinicians treating periodontitis [1]. These factors must be thoroughly evaluated during treatment planning and supportive periodontal therapy, as they significantly influence disease recurrence and prognosis. Effective management of periodontitis hinges on an accurate diagnosis that accounts for the disease's etiology, various risk and prognostic factors, and the practitioner's skills [2].

Periodontal treatment can be broadly classified into nonsurgical and surgical therapies, with the latter further divided into respective and regenerative procedures. When choosing the appropriate treatment, clinicians must consider factors such as disease severity and progression rate [3]. However, despite careful assessment and optimal therapy, the long-term prognosis of periodontitis remains uncertain due to the multitude of influencing factors, making precise assessment challenging in practice.

Well-known factors affecting periodontal prognosis include smoking, diabetes, plaque levels, and tooth type [4]. Johnson et al. have claimed that a "high risk group" of periodontitis exists and that a scientific approach must be used to target these

patients for prevention and treatment, while Lang et al. have proposed a periodontal risk assessment (PRA) based on a functional diagram that includes the following 6 factors: Bleeding on Probing (BOP), Probing Depth (PD), Genetic factors, Tooth Loss (TL), Bone Loss (BL)/Age, and Environmental factors [5, 6]. Page et al. have devised a computer-based risk assessment tool to accurately predict the course of periodontal disease, and they reported that their risk calculator can be used to assist a practitioner to make a decision by predicting disease severity and tooth loss [7, 8]. Teich et al. have also reported the utility of the computer-based RABIT (risk assessment-based individual treatment) system for periodontal risk assessment, and many other attempts of using PRA to predict the prognosis of periodontal disease and applying the prediction to treatment plans, supportive periodontal therapy, as well as prognosis of periodontal disease are still being continued today [9-12].

Despite extensive research since the late 1970s, determining periodontal prognosis remains complex due to the interplay of numerous patient and practitioner-related variables [13-21]. Recently in 2021, Farina et al. used the PerioRisk model, which was devised by Trombelli et al. in 2009 and incorporates smoking, diabetes, PD, BOP, and BL/age as risk factors, to study the effects of different periodic recall check intervals on TL in 168 patients with periodontitis with different periodontal risk levels. In their research, they concluded that PerioRisk is an effective tool for determining the recall interval before conducting supportive periodontal therapy [22, 23]. In 2022, Rahim-Wöstefeld, et al. analyzed tooth-related risk factors and patient-related risk factors in order to predict TL in active periodontal treatment and reported that abutment function, diabetes, BL, furcation involvement (FI), and age can be used as prognostic tools [24].

However, despite the continued rigorous research, it is still very difficult for both general practitioners and periodontists to determine periodontal prognosis, because it depends on the combined effect of a host of variables that involves both the patient and the practitioner. Moreover, prognosis can change over time based on therapeutic methods and patient compliance, making it a dynamic and challenging task for clinicians [25]. For such reasons, classifying periodontal prognosis is exceedingly complicated and difficult for clinicians. For example, there are many cases where teeth classified as hopeless prognosis have improved to good prognosis after a long period of therapy through the efforts of the practitioner and the patient. On the contrary, the opposite is also possible where good prognosis for a tooth turns into hopeless (Figure 1). Additionally, existing prognostic tools often rely on subjective judgments, highlighting the need for a more objective and consistent system. With the increasing prevalence of dental implants, there's also a tendency to favor extractions over periodontal treatment, further underscoring the need for an effective prognostic system that helps preserve natural teeth.

The 2017 Classification of Periodontitis (the 2017 classification) incorporates some prognostic capabilities, enabling clinicians to predict disease progression to a certain extent. Recent studies, such as those by Ravida et al., have validated the predictive capacity of the 2017 classification by examining extraction rates [26, 27]. However, research specifically focused on the limitations and potential of the 2017 classification's prognostic function is scarce. This study aims to evaluate the 2017 classification's significance from a prognostic perspective beyond tooth loss and to compare it with previous major prognostic systems through a systematic review. Furthermore, we propose a novel, simpler, and more efficient prognostic system to enhance clinical practice in treating periodontitis.

Figure 1: A. Clinical case in which the prognosis was changed from hopeless prognosis to good prognosis after regenerative surgery and complete supportive periodontal therapy (central incisor on the right mandible).

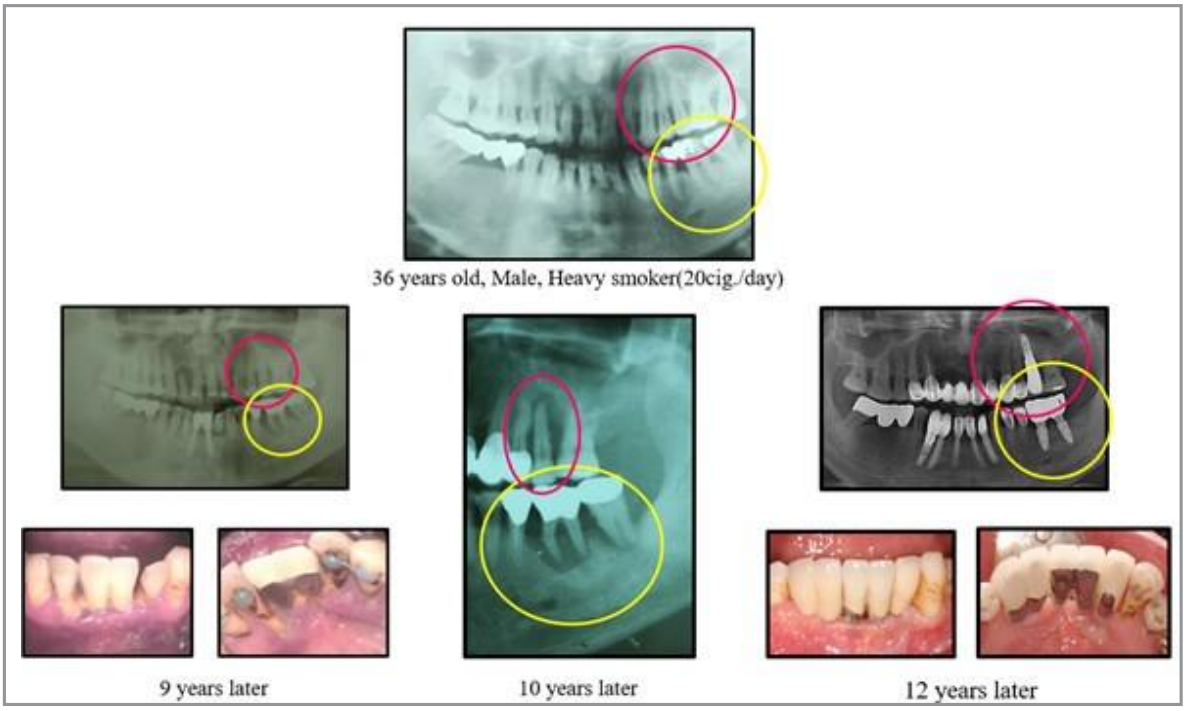


Figure 1: B. Clinical case in which the prognosis changed from good prognosis to hopeless prognosis after 10 years due to erratic compliance (second premolar on the left maxilla, first molar & second molar on the left mandible). However, with active periodontal therapy, implant treatment and complete compliance, it was possible to gain healthy periodontium again.

Methods

This systematic review was conducted following the six categories and 27 checklists of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [28]. A total of 89 articles were selected for this study (Fig. 2). A color gradient scale was used to compare the 2017 classification with previous prognostic systems.

Search Strategy

We selected articles for this study through database searches on Medline, ScienceDirect, and Google Scholar. Keywords used included "periodontal prognosis/prognosis & periodontitis/prognostication & periodontitis," "prognostic model & periodontitis/periodontal disease," "risk factor & periodontitis/periodontal disease," "risk assessment & periodontitis/periodontal disease," and "prognostic factor & periodontitis/periodontal disease." Additionally, a hand search was conducted to find related journals.

Inclusion Criteria

Articles clearly related to this topic and not related to implants were selected. Included papers focused on studies of factors affecting periodontal prognosis, evaluation methods of prognosis, systems for periodontal prognosis, short-term and long-term outcomes for prognosis, patient-level risk factors (such as age, genetics, obesity, alcohol, diabetes, and smoking), and tooth-level risk factors (such as furcation, root proximity, and probing depth). Selected papers were divided into two groups: "periodontal prognosis" and "periodontal risk assessment."

Exclusion Criteria

Articles were excluded based on the following criteria.

1. Studies done before 1970.
2. Studies focused on periodontal materials.
3. Studies focused on epidemiology.
4. Studies focused on classification.
5. Studies focused on probing method.

Data Extraction

Two independent investigators collected articles after discussion and calibration to eliminate errors and mistakes. For the analysis of periodontal prognosis, data were extracted using a standardized protocol, including the name of the first author, publication year, study design, evaluated items for the prognostic system, classification of prognosis, criteria of each category, duration of research, patient's age, and outcomes. For the analysis of periodontal risk assessment, extracted data included the name of the first author, publication year, method of study, the name of the risk assessment system/model, the number of patients, used variables, criteria of parameters, evaluation grade, results, strengths, and limitations.

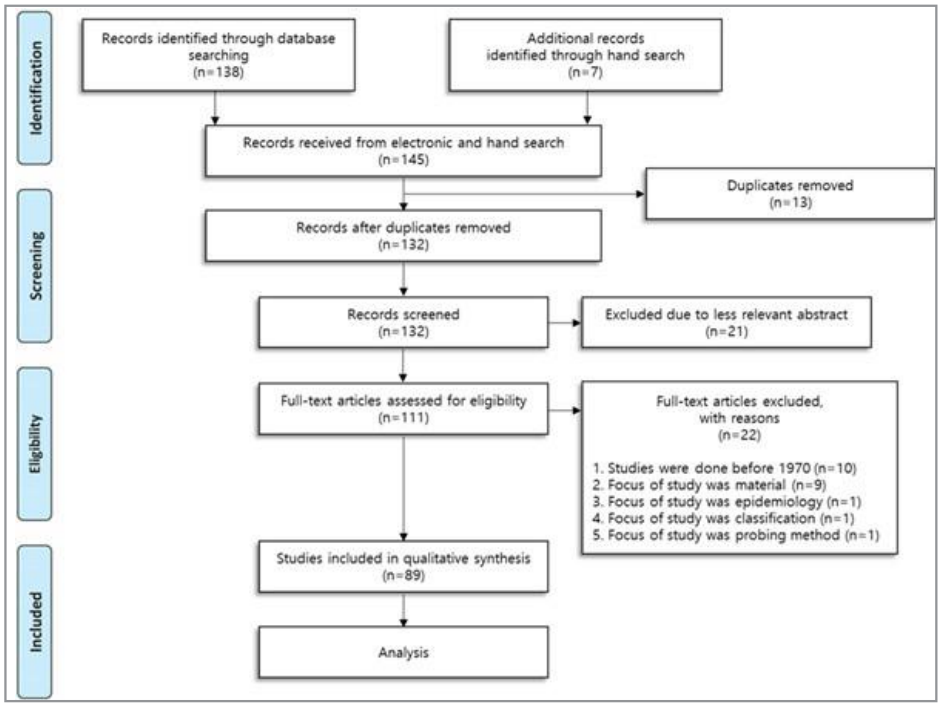


Figure 2: Flowchart of the systematic review process by following the PRISMA protocol

Results

Review of Previous Classifications for Periodontal Prognosis

Few studies have thoroughly evaluated periodontal prognosis (Table 1). This scarcity is likely due to the complexity of accurately determining prognosis for a multifactorial disease like periodontitis, where many factors are intertwined. Early taxonomy and research were simple and unsophisticated. The first known classification of periodontal prognosis was by Hirschfeld et al. in 1978, dividing the categories into favorable and questionable prognosis [13]. Becker et al. later clarified the conditions of questionable prognosis and added hopeless prognosis to their classification, emphasizing the importance of maintenance by reporting differences in prognosis with and without maintenance [15, 29]. The foundation of modern periodontal prognosis classifications was established by McGuire (Table 1, Figure 3B). He analyzed various factors to classify prognosis, dividing them into factors for individual tooth prognosis and factors for overall prognosis. Factors for individual tooth prognosis included percentage of bone loss (BL), probing depth (PD), mobility, and furcation involvement (FI), among other miscellaneous factors. For overall prognosis, the factors were age, medical status, patient cooperation, and the dentist's ability. McGuire categorized periodontal prognosis into good, fair, poor, questionable, and hopeless. Conditions for these categories were defined as follows:

- **Good:** Adequate periodontal support and assurance of easy maintenance
- **Fair:** Mild attachment loss and Class I FI
- **Poor:** Moderate attachment loss, Class I and/or Class II FI
- **Questionable:** Severe attachment loss, Class II or Class III FI, and mobility degree greater than 2 or 3
- **Hopeless:** Inadequate attachment to maintain

McGuire's significant contribution was his report on how initially determined prognosis changed over the long term. His prognostic system has been validated by other researchers who suggested similar classifications [19, 30].

Kwok and Caton advanced McGuire's concepts and classifications (Table 1, Figure 3C) [20].

They introduced three important concepts for prognosis:

1. Periodontal stability, which should be continuously evaluated by attachment loss and radiographic BL.
2. Timing for detecting dynamic changes during maintenance.
3. Consideration of both individual tooth prognosis and overall prognosis.

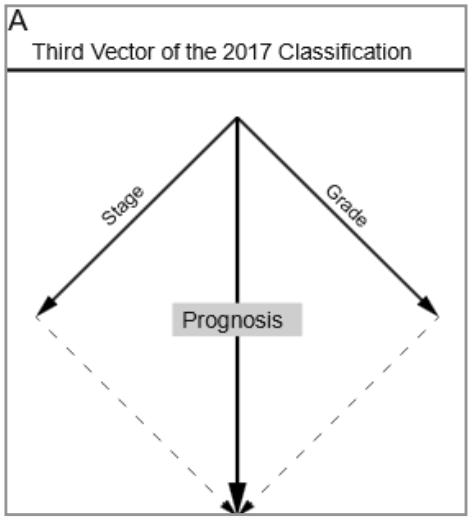
Based on these components, they proposed a new prognostic system divided into four categories: favorable, questionable, unfavorable, and hopeless.

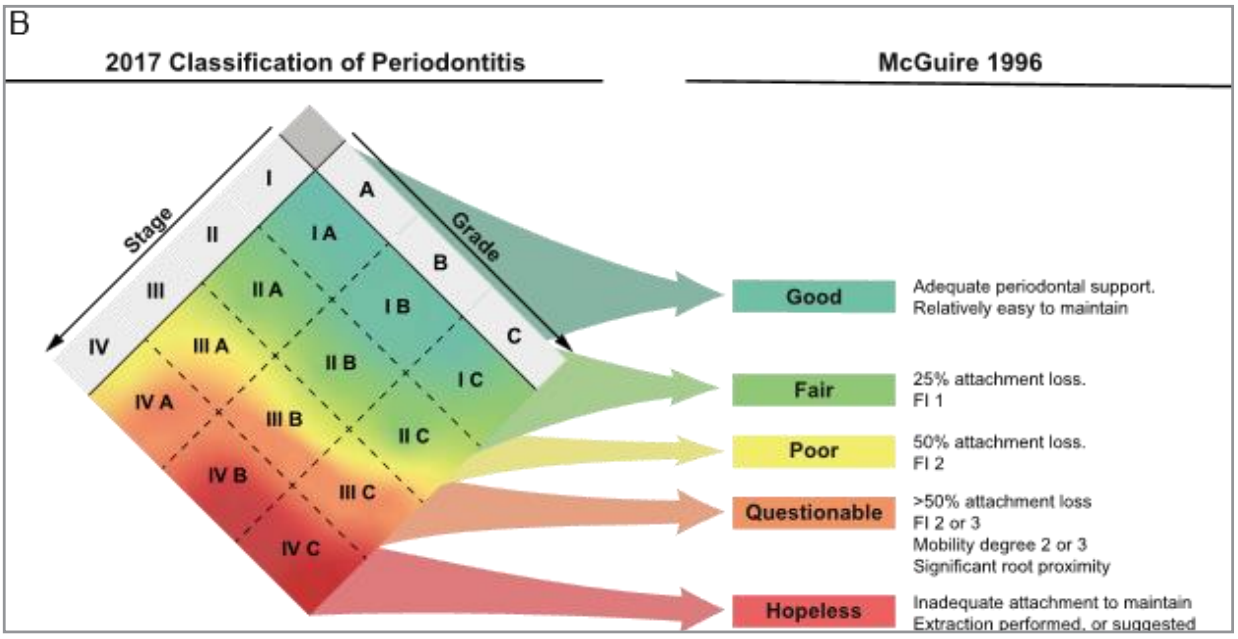
- Favorable prognosis: Periodontal stability is likely to be maintained if local and systemic factors can be controlled with treatment and maintenance.
- Questionable prognosis: Periodontal stability may be maintained if local and systemic factors are controlled with treatment and maintenance, though breakdown may occur under other conditions.
- Unfavorable prognosis: Local and systemic factors cannot be controlled, making periodontal stability unlikely to be maintained.
- Hopeless prognosis: Extraction is recommended.

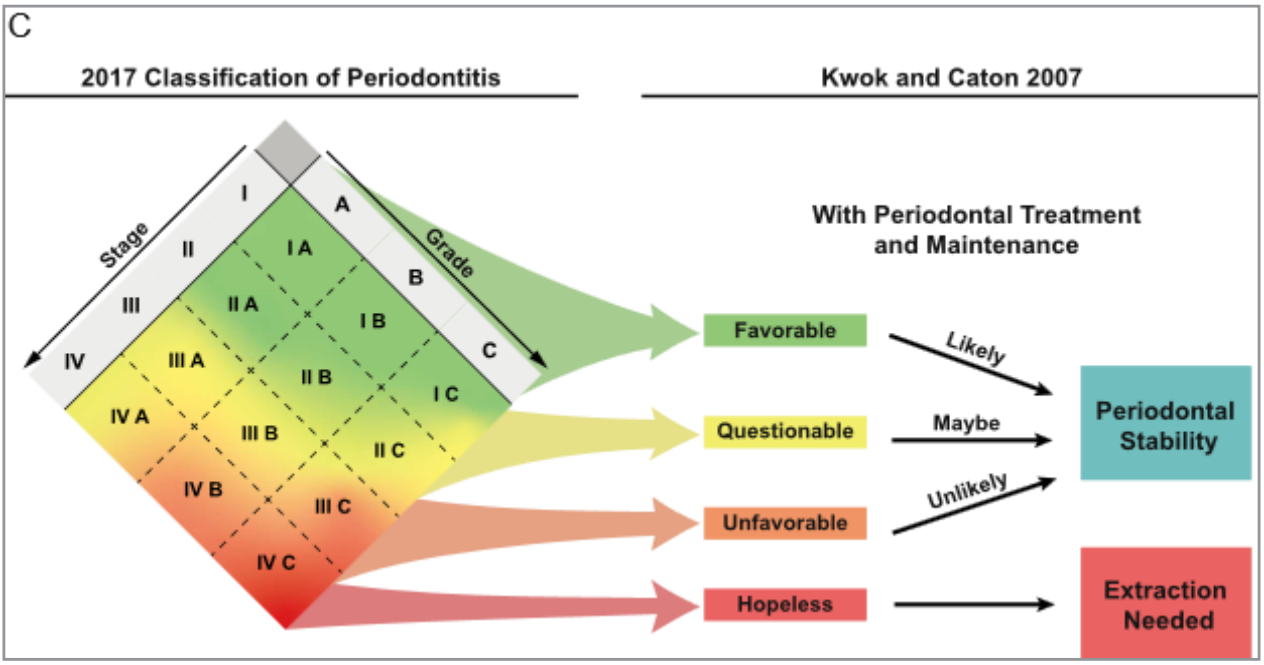
They concluded that their system requires long-term verification and adaptation, and several similar suggestions have been made since Kwok and Caton devised their prognostic system [21, 31, 32].

Table 1. Summary of previous prognostication systems.

	Hirschfeld 1978	McFall 1982	Becker 1984 (J Periodontol)	Becker 1984(JPRD)	Wilson 1987	McGuire 1991	McGuire 1996	Checchi 2002	Fartal 2004	Kwok 2007	Tsami 2009	Nibali 2017	McGowan 2017
What the System Evaluates	Tooth loss; FI	Tooth loss, FI	Tooth loss, PD, FI	Tooth loss; PD, FI	Tooth loss	Tooth loss	Tooth loss	Tooth loss	Tooth loss	Stability##	Tooth loss	Tooth loss	N/A
Classification of prognosis	Favorable	Favorable	Good	Good	Good	Good	Good	Good	Good	Favorable	Good	Favorable	Secure
	Questionable	Questionable	Questionable	Questionable	Fair	Fair	Fair	Questionable	Uncertain	Questionable	Moderate	Fair	Doubtful
			Hopeless	Hopeless	Poor	Poor	Poor	Hopeless	Poor	Unfavorable	Guarded	Questionable	Poor
						Questionable	Questionable		Hopeless	Hopeless	Hopeless	Unfavorable	Irrational to treat
						Hopeless (retained)	Hopeless						
						Hopeless (extracted)							
Notes on Each Classification	Response to therapy; Well-maintained (WM), Downhill (D), Extreme downhill (ED)	WM, D, ED				Individual tooth prognosis & overall prognosis	Individual tooth prognosis & overall prognosis						
Criteria for each category	1. Favorable: no mention, 2. Questionable (one or more of the following): FI, deep nonradicable pocket, extensive alveolar bone loss, marked mobility (degree 2–2.5) a/w PD	Same as Hirschfeld 1978	1. Good: no mention, 2. Questionable: 50% bone loss/tooth length, PD 6–8mm, FI III, deep vertical developmental groove, mesial FI of maxillary first bicuspid, extensive decay (not resorable), 3. Hopeless: 75% bone loss/root length, PD >8mm, FI III, mobility class III, poor crown-root ratio, root proximity & horizontal bone loss, history of repeated abscess	1. Good: no mention, 2. Questionable: 50% bone loss/tooth length, PD 6–8mm, FI III, deep vertical developmental groove, mesial FI of maxillary first bicuspid, extensive decay (not resorable), 3. Hopeless: 75% bone loss/root length, PD ≥8–10mm, FI III, hypermobility, poor crown-root ratio, root proximity, history of repeated abscess	No mention	* Premise of 1 (good)–4questionable); one or more of following conditions. 1. Good: adequate support, relatively easy to maintain, 2. Fair: mild AL, FI I, 3. Poor: moderate AL with FI I or II, 4. Questionable severe AL, FI II or III, mobility degree≥2, 5. Hopeless: inadequate AL in health, comfort & function (extraction was performed or suggested).	* Premise of 1 (good)–4questionable); one or more of following conditions. 1. Good: adequate support, relatively easy to maintain, 2. Fair: 25% AL & BL, FI I, 3. Poor: 50% AL with FI I or II, 4. Questionable: >50% AL, FI II or III, mobility degree≥2, 5. Hopeless: inadequate AL in health, comfort & function (extraction was performed or suggested).	* Radiographic examination: 1. Good: <30% bone loss/tooth length, no FI, no angular bony defect 2. Questionable: 30–75% bone loss or angular bony defect≥2/mm or FI ≥ 3. Hopeless: >75% bone loss or at least 2 conditions of questionable	1. Good: PD<3mm & proximal BL<1/3, 2. Uncertain: PD 4–6mm & BL 1/3–2/3 & BOP, FI≤4, 3. Poor: PD≥7mm & >2/3 BL & BOP, FI≥4, mobility>1mm, 4. Hopeless:PD≥9mm, BOP, mobility>1mm, FI III	1. Favorable: "likely" stability/further loss does not occur), 2. Questionable: "maybe" stability/if the local/ systemic factors are controlled, further loss does not occur but otherwise breakdown occurs. 3. Unfavorable: "unlikely" stability/factors cannot be controlled & further loss occurs), 4. Hopeless: must be extracted	1. Good: adequate support, easy to maintain, 2. Moderate: <30% AL, FI I or II, allow maintenance to good compler, 3. Guarded: ≥30% AL, poor root form, FI II or III, mobility degree≥2, 4. Hopeless: inadequate attachment in health, comfort and function	1. Good: bone loss <25%, mobility degree≤1, FI≤I, PDmm≤6mm, 2. Fair: bone loss 25–50%, mobility degree≤1 FI≤II, PDmm≤6mm, 3. Questionable: bone loss 25–50%, mobility degree>1, FI>1, PD>6mm) or (bone loss >50–<70%) or (bone loss≥70%, FI≤2, mobility degree≤2), 4. Unfavorable: bone loss≥70%, FI>2 or mobility degree >2	1. Secure: no future loss over 10years, BL age<0.5, PD≤5mm, 2. Doubtful: stable over 5 years, BL/age 0.5–1.0, PD 6–7mm, FI II, mobility>1, untreated infrabony defect, tooth anatomic factors, 3. Poor: breakdown is likely over next 5 years, BL/age> 1.0, PD≥8mm, FI III, progressive mobility, 4. Irrational to treat: circumferential bone loss to the apex, vertical mobility
Supplemental criteria	WM, 0–3 teeth loss, D, 4–9 teeth loss, ED;10–23 teeth loss (on the basis of response to therapy)	Same as Hirschfeld 1978											Downgrade 1 level to a maximum of poor if one or more followings (patient-related factors): 1. smoking>1pack/day), 2. HbA1c≥9.3. ≥30% BOP sites
Duration of Research	15–53 years(average 22 years)	15–29 years (average 19years)	Average ≤25 years	3–11 years	At least 5 years	5–11 years	At least 5 years	3–12 years	9–11years		8–16 years	At least 5 years	
Age	12–73 (at initial)	8–71	44 (median)	25–74 (at initial)	N/A	22–79(at initial)	<40, 40–49, ≥50	28–65	25–69		43–62	Average 53.04	
Number of patients	600	100	44	95	162	100	100	92	100		280	100	
Study design	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Retrospective, longitudinal	Review	Retrospective, longitudinal	Retrospective, longitudinal	Review
Outcomes	Patient's no. of group; 499 (WM), 76 (D), 25 (ED); Questionable prognosis %; 17.1% (WM), 64.7% (D), 88.4% (ED), while the prognosis of maxillary molar was worst, mandibular canine was the best. 666 of 2139 teeth (31%) that been categorized into questionable prognosis were extracted.	Patient's no. of group; 77 (WM), 15 (D), 8 (ED); Questionable prognosis %; 27% (WM), 77.3% (D), 91.8% (ED)	Treatment without maintenance is little value. 72.9% of initial PD 1–3mm, 62% of PD 4–6mm, 31.6% of PD>7mm were not changed. Worsening of FI; 22.6%	The rate of tooth loss of initial good: 1.7%, the rate of tooth loss of nonhopeless: 2.94%, the rate of over all tooth loss: 6.21%, 80.4% of initial hopeless was extracted.	Time to extraction of tooth loss for periodontal reason; 4.3 years (good), 4.1years (fair), 2.18 (poor)	82.9% of initial good, 40.6% of fair, 27.4% of poor, 0% of questionable and 61.5% of hopeless were not changed after 5 years.	Survival rate: 71.2% of initial good, 20.3% of fair, 6.3% of poor, 1.4% of questionable, 0.8% of hopeless, risk ratio of tooth loss for combination fair and poor: 1.799, risk ratio of tooth loss for combination questionable and hopeless 5.920	The rate of tooth loss: 0.07% (Good), 3.63% (Questionable), 11.34% (Hopeless), the risk of tooth loss of erratic complier: 5.6 times	75% (27teeth) of total extracted teeth (36) a/w uncertain, poor & hopeless initial prognosis (25% a/w good prognosis). 1.5% of total teeth (2436 teeth) was lost due to periodontal reason. 67% of initial hopeless, 9% of poor, 3% of initial uncertain and 0.46% of initial good prognosis were extracted during maintenance.	Three essential elements for prognosis: 1. stability, 2. timing for detecting dynamic change during maintenance, 3. consideratin of both individual tooth prognosis & overall prognosis.	Initial tooth prognosis, tooth type, compliance (the risk ratio of erratic complier=1.52) and smoking (mortality ratio is 4.22 times greater) affected tooth loss.	Prognosis systems may estimate the risk of tooth loss (initial prognosis odds ratio of tooth loss: 6.92)	9 evidence-based quantifiable parameters may provide accurate prognosis & for tooth level (BL/age, PD, FI, infrabony defect, anatomic factros, mobility), 3 tier patient level (smoking, diabetes, BOP)
Remarks	With maintenance after treatment	With maintenance after treatment	Without maintenance after treatment	With treatment & maintenance(mean 5.2months)	With maintenance, erratic compliers lost more teeth.	Ineffective in predicting except good prognosis	With maintenance(≥2–3months)	Prognosis index=(No. of questionable + No. of hopeless)/No. of total teeth; Category A: <0.27(~25%), B0.27–0.5(25–75%), C>0.5(>75%)	With maintenance(1–2 visits/year)	Suggestion	Greek population	Combined with periapical index score(Ortakwik et al. 1986)	Proposed prognosis model, combined with patient-level risk: smoking, diabetes, BOP %, compliance is mandatory


A
Third Vector of the 2017 Classification
Stage
Grade
Prognosis


B
2017 Classification of Periodontitis
McGuire 1996
Stage
I
II
III
IV
Grade
A
B
C
I A
I B
I C
II A
II B
II C
III A
III B
III C
IV A
IV B
IV C
Good
Adequate periodontal support.
Relatively easy to maintain
Fair
25% attachment loss.
FI 1
Poor
50% attachment loss.
FI 2
Questionable
>50% attachment loss
FI 2 or 3
Mobility degree 2 or 3
Significant root proximity
Hopeless
Inadequate attachment to maintain
Extraction performed, or suggested


C
2017 Classification of Periodontitis
Kwok and Caton 2007
With Periodontal Treatment
and Maintenance
Stage
I
II
III
IV
Grade
A
B
C
I A
I B
I C
II A
II B
II C
III A
III B
III C
IV A
IV B
IV C
Favorable
Likely
Questionable
Maybe
Unfavorable
Unlikely
Hopeless
Periodontal Stability
Extraction Needed

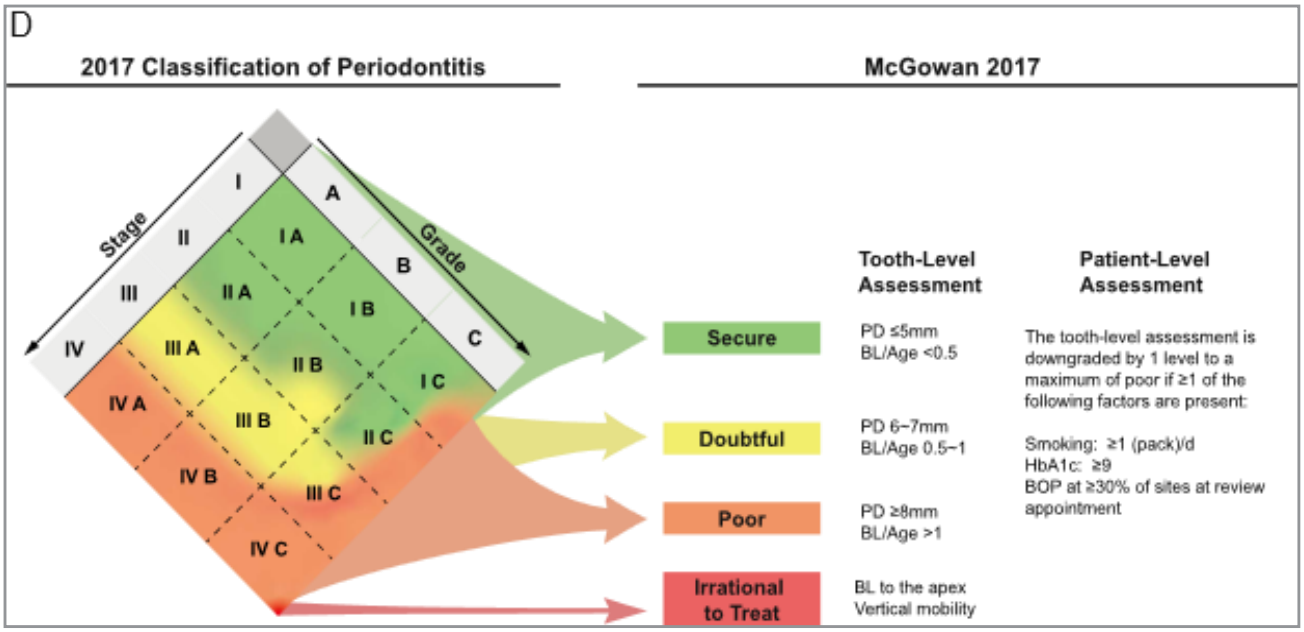


Figure 3: Comparison between the 2017 classification and prognostic classifications in the past. A) The 2017 classification is in fact a 3-vector system. B) Comparing the prognostic classification of McGuire 1996 and the 2017 classification [17]. C) Comparing the prognostic classification of Kwok 2007 and the 2017 classification [20]. D) Comparing the prognostic classification of McGowan "2017." and the 2017 classification [21]. Dotted lines and color gradient scales were used to visually represent the uncertainties regarding prognostic boundaries between each set of stage and grade. FI, furcation involvement; BL, bone loss; BOP, bleeding on probing; HbA1c = glycated hemoglobin A1c.

Comparing the 2017 Classification with Previous Prognostic Systems

The 2017 classification of periodontitis represents a paradigm shift by incorporating risk and prognostic factors, thus allowing for a certain degree of prognostication. This necessitates an evaluation of how it compares with existing prognostic systems and what its limitations might be. In this study, we compared three major prognostic systems: McGuire's system, Kwok's system, and McGowan's system (Figure 3, Table 2).

The reason we chose McGuire's system is that it serves as the foundation of most, if not all, modern prognostic systems, and most other systems are similar to his system. Kwok's system was selected for its unique incorporation of periodontal stability, and McGowan's system was included for its recent introduction and inclusion of both patient-related and tooth-related factors.

Comparison with McGuire's System: McGuire's system is well-regarded for its comprehensive approach to prognosis, classifying it into good, fair, poor, questionable, and hopeless categories. Comparing this with the 2017 classification:

- Stage I, Grade A/B corresponds to McGuire's Good prognosis.
- Stage I, Grade C and Stage II, Grade A/B align with Fair prognosis.
- Stage II, Grade C and Stage III, Grade A/B align with Poor prognosis.
- Stage III, Grade C and Stage IV, Grade A are akin to Questionable prognosis.
- Stage IV, Grade B correlates with Questionable or Hopeless prognosis.
- Stage IV, Grade C matches with Hopeless prognosis.

Although the match is not exact, clinicians can reasonably infer prognosis by translating the 2017 classification into McGuire's system.

Comparison with Kwok's System: Kwok's system focuses on periodontal stability, classifying prognosis as favorable, questionable, unfavorable, and hopeless:

- Stage I/II, Grade A/B corresponds to Favorable prognosis.
- Stage II/III, Grade B/C align with Questionable prognosis.
- Stage III/IV, Grade C align with Unfavorable prognosis.
- Stage IV, Grade C matches Hopeless prognosis.

While Kwok's system integrates the innovative concept of stability, direct comparison with the 2017 classification remains challenging due to the abstract nature of stability. Nonetheless, the gradient analysis shows a more even match with the 2017 classification than McGuire's system.

Comparison with McGowan's System: McGowan's system, which includes patient-related factors (e.g., smoking, diabetes) and tooth-related factors, aligns with the 2017 classification as follows:

- Stage I, Grade A/B or C and Stage II, Grade A/B correspond to Secure prognosis.
- Stage II, Grade C and Stage III, Grade A/B align with Doubtful prognosis.

- Stage III, Grade C and Stage IV, Grade B match with Poor prognosis.
- Stage IV, Grade C equates to Poor prognosis or Irrational to treat.

McGowan's system's emphasis on patient-related factors makes it the most conceptually aligned with the 2017 classification. When compared, Kwok's system's Questionable prognosis matches the widest range of the 2017 classification stages and grades, whereas McGowan's system's Poor prognosis covers the most extensive area. McGuire's hopeless prognosis criteria span a broader area of the 2017 classification compared to the other systems.

Table 2: Comparison of the 2017 classification with previous prognostic systems. CAL, clinical attachment loss

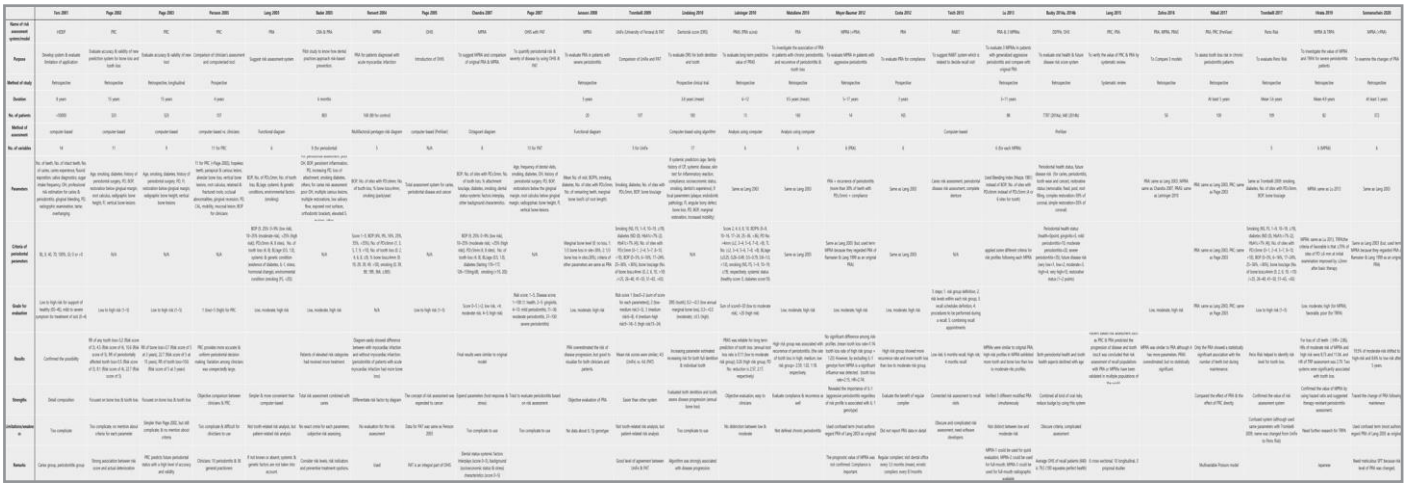
2017 classification of periodontitis	Conditions	Compared with McGuire 1996	Compared with Kwok 2007	Compared with McGowan 2017
Stage I Grade A, B	1~2mm CAL +<2mm/ 5years additional CAL + no complexity	Good	Favorable	Secure
Stage I Grade C, Stage II Grade A, B	1-2mm CAL + ≥2mm/ 5years CAL (or 3-4mm CAL + <2mm/5 years CAL) + no complexity	Fair	Favorable	Secure
Stage II Grade C	3-4mm CAL + ≥2mm/ 5years + no complexity	Fair or Poor	Questionable	Doubtful
Stage III Grade A, B	≥5mm CAL + < 2mm/ 5years + simple (complexity)	Poor	Questionable	Doubtful
Stage III Grade C	≥5mm CAL + ≥ 2mm/ 5years + simple (complexity)	Poor or Questionable	Questionable	Poor
Stage IV Grade A	≥5mm CAL + 0mm/ 5years + complex (complexity)	Questionable	Questionable	Poor
Stage IV Grade B	≥5mm CAL + <2mm/ 5years + complex (complexity)	Hopeless (retaintion) or hopeless (extraction)	Unfavorable	Poor
Stage IV Grade C	≥5mm CAL + ≥2mm/ 5years + complex (complexity)	Hopeless (retaintion) or hopeless (extraction)	Unfavorable or Hopeless	Poor or Irrational to treat

Review of Risk Assessment Systems/Models

Alongside periodontal prognostic systems, periodontal risk assessment systems (PRAs) have been the focus of study and development by numerous researchers [6, 8, 10, 32-54]. Theoretically, a prognostic system for periodontitis should be based on prognostic factors, while PRA systems should be based on risk factors, which encompass multiple factors causing the disease. Periodontal risk factors can significantly impact the severity of the disease, although intervening with these factors does not always guarantee favorable outcomes [55-57]. Conversely, prognostic factors, such as patient compliance, share similarities with risk factors but are more directly linked to ensuring favorable results [56]. Some risk factors, such as smoking, are also categorized as prognostic factors. Thus, while analyzing factors related to the prognostic aspects of the 2017 classification should ideally focus on prognostic factors, reviewing previous PRA systems/models is also necessary due to the challenge of distinguishing between prognostic and risk factors.

Numerous PRA systems/models have been reported thus far (Table 3). Page et al. developed a PRA system using the periodontal risk calculator (PRC). In the early stages of their study, their team incorporated 9 to 13 risk factors [8, 39]. However, the PRC faced limited adoption by clinicians due to unclear criteria for each parameter and overly complicated software. In 2003, Lang et al. developed their own PRA system, designed to enable clinicians to determine risk at a glance using a hexagonal diagram featuring six parameters: BOP%, number of PD≥5mm, number of tooth loss (TL), BL/age, systemic & genetic conditions, and environmental factors [10, 38, 46, 49]. Since then, PRA has evolved into several modified versions. However, most PRA systems/models developed thus far remain overly complex and lack objective verification for clinical use. Consequently, further research and consensus are warranted to simplify and validate these systems. Please find the table here: Table 3

Table 3: Summary of periodontal risk assessment systems/models.



PRC, periodontal risk calculator; HIDEP, Health Improvement in Dental Practice Model; BL, bone loss; PD, pocket depth; BOP, bleeding on probing; RR, relative risk; CRA, caries risk assessment; OH, oral hygiene; OHIS, oral health information suite; PAT, periodontal assessment tool; NS, never smoker; FS, former smoker; ND, non-diabetic; CP, chronic periodontitis; MPRA, modified periodontal risk assessment; TL, tooth loss; HR, hazard ratio; RABIT, risk assessment-based individualized treatment; DEPPA, denplan excel/previser patient assessment; OHS, oral health score; TRPA, therapy-resistant periodontitis assessment; SPT, supportive periodontal therapy.

Discussion

Comparing Existing Prognostic Systems with the 2017 Classification

The review of previous periodontal prognosis systems revealed a significant evolution in the approach to prognosis assessment. Earlier systems, though simple, lacked accuracy. However, in 1996, McGuire introduced a systematic prognostic model that laid the foundation for modern prognostic systems, with many contemporary models drawing from his work (Table 1). Subsequently, Kwok and Caton advanced the concept further in 2007, although their model, lacking clinical grounding, struggled for practical application. In 2017, McGowan introduced a comprehensive system that incorporated patient-level factors, such as smoking and HbA1c, alongside tooth-level assessment. While significant, McGowan's system's reliance on only two parameters—PD and BL/age—for tooth-level assessment renders it insufficient for accurate periodontal prognosis due to the multifactorial nature of the disease.

Our comparative analysis using a color gradient scale revealed Kwok and Caton's system to have the most balanced match with the prognostic capabilities of the 2017 classification (Fig. 3C). This could be attributed to its theoretical basis. Conversely, McGowan's system, with its numerous parameters, showed poor alignment with the 2017 classification, particularly in the "irrational to treat" category (Fig. 3D). McGuire's system demonstrated a somewhat balanced match for the "good" and "fair" categories but struggled with defining boundaries between "poor", "questionable", and "hopeless" (Fig. 3B).

Reviewing risk assessment systems revealed that many are based on Lang et al.'s functional diagram from 2003. The parameters used in this diagram—BOP, PD≥5mm, TL, BL/age, systemic & genetic conditions, and environmental factors (smoking)—remain prevalent in determining periodontal prognosis (Table 3).

Proposal: A Novel Periodontal Prognostic Scale (PPS) System

Despite continuous improvements in prognostic systems, their combinations and criteria for each parameter remain ambiguous. Additionally, most prognostic classifications fail to distinguish between patient-level, tooth-level, and site-level prognostic factors, leading to complexity and difficulty for clinicians in objectively determining periodontal prognosis [16, 20, 21]. Consequently, accurately establishing the prognosis of periodontitis and devising treatment plans for patients has proven challenging [58]. The complexity of existing prognostic systems stems from the intricate interplay of numerous confounding factors in periodontitis, leading to diverse outcomes [59, 60].

Even if scientifically proven data underpin an accurate prognostic system, its clinical practicability is compromised if it is too complex for clinicians to understand and use effectively. Therefore, prioritizing ease of use and practicality over absolute accuracy could be a reasonable approach. Accuracy can be refined over time through subsequent updates and adjustments of parameters and criteria. An analogy can be drawn from credit ratings used by banks and credit card companies. They evaluate a customer's credit using various parameters, such as annual salary and mortgage condition, and assign a credit score based on the sum of these parameters. The accuracy of predictions is periodically reassessed, and adjustments are made to improve the reliability of credit scores. Similarly, the proposed Periodontal Prognostic Scale (PPS) system aims for ease of use and practicality. Accuracy can be refined over time through subsequent updates and adjustments of parameters and criteria. An analogy can be drawn from credit ratings used by banks and credit card companies. They evaluate a customer's credit using various parameters, such as annual salary and mortgage condition, and assign a credit score based on the sum of these parameters. The accuracy of predictions is periodically reassessed, and adjustments are made to improve the reliability of credit scores. Similarly, the proposed Periodontal Prognostic Scale (PPS) system aims for ease of use and practicality.

The PPS system eliminates potential confusion by determining prognosis for each tooth rather than at the patient level. It comprises 10 to 12 parameters necessary for assessing prognosis, each scored from 0 to 3 for intuitive division (Table 4; Table 5). Clinicians can estimate prognosis by totaling parameter scores. The system categorizes prognosis into five categories—good, fair, poor, questionable, and hopeless—based on McGuire's prognostic system. This intentional choice leverages McGuire's system as the foundation of current prognostic systems, aiding familiarity for clinicians. Unlike previous prognostic systems, the PPS system incorporates new variables such as alcohol consumption, compliance, combined lesion, clinician experience, and stress to enhance periodontal prognosis prediction. This broader scope aims to provide a more comprehensive assessment of prognostic factors, facilitating improved treatment planning and patient care.

Table 4. The novel periodontal prognostic scale (PPS) system.

			Parameters	Score 0	Score 1	Score 2	Score 3	Related articles	Remarks
PPS-12	PPS-11	PPS-10	PD	≤3mm	4~6mm	7~8mm	≥9mm	Fardal 2004, Matuliene 2008,	
			%BL/root length	0~<=25%	25~<=50%	50~<=75%	>75%	Taylor 1998, Graetz 2017	
			FI (for multi-root)	Normal	Degree I	Degree II	Degree III	Matuliene 2008, Graetz 2015	
			Crown-root ratio (for sin-gle-root)	<0.5 (1:2)	0.5 (1:2)~0.8 (1:1.25)	0.8 (1:1.25)~<1.0 (1:1)	>1.0 (1:1)	Martinez-Canut 2015	
			Mobility	Normal	Degree I	Degree II	Degree III	Matuliene 2008, Graetz 2017	
			Root proximity	>1.5mm	0.8~1.5mm	0.6~0.8mm	<0.6mm	Vermylen 2005, Kim 2008	
			Combined lesion	No combined	Endo-periodontal lesion	Perio-endodontic lesion	True combined	Rotstein 2004, Shenoy 2010, Bonaccorso 2014	Further research is needed.
			Smoking (self-reported)	NS, FS (over 13years)	FS (less than 13yrs), 1~19cig./d	20~30cig./d	≥31cig./d	Tomar 2000, Calsina 2002, Krall 2006	
			Alcohol (self-reported)	0~3units/week (light drinker both female & male)	4~7units/week (light driker for male & moderate drinker for female)	8~14units/week (moderate drinker for male & heavy drinker for female)	>14 units/week (heavy drinker for both male & female)	Tezal 2004, Hach 2015	Classification of Hach 2015, 1 unit=12.5g of pure alcohol (=a bottle of beer(355ml, 4.5%)
			Compliance	Comlete (100%)	75% of total requested SPT	50% of total requested SPT	Non complier (0%)	Pretzl 2008, Tsami 2009, Matuliene 2010, Silva 2014	
			Level of clinician	Periodontist with more than 10 years experiences	Periodontist with under 10 years experiences	GP with more than 3 years experiences	GP with under 3 years experiences	McGuire 1991, McGuire 1996	Further research is needed.
			Diabetes	HbA1c <6%	HbA1c 6~<7.5%	HbA1c 7.5~<9.5%	HbA1c >9.5%	Christgau 1998, Lalla 2006	
			Stress	0~13	14~26	27~40	Pateints being treated for stress or depression	Genco 1999, Hilgert 2006	Total score of perceived stress scale-10 (Cohen 1988)

	Good prognosis	Fair prognosis	Poor prognosis	Questionable prognosis	Hopeless prognosis
Expected survival period	More than 10 years	5 to 10 years	3 to 5 years	1 to 3 years	less than 1 year
PPS-10 (total 30)	0~6	6~12	13~17	18~24	25~30
PPS-11 (total 33)	0~6	6~12	13~20	21~27	28~33
PPS-12 (total 36)	0~6	6~12	13~23	24~30	31~36

PPS, periodontal prognostic scale; BL, bone loss; FI, furcation involvement; NS, nonsmoker; FS, former smoker; SPT, supportive periodontal therapy.

Table 5: Perceived stress scale-10 & scoring rule to evaluate patient's stress [61], [62]

	Respond to each question by marking on box per row	Never	Almost never	Somtimes	Often	Very often
PSS 1	In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
PSS 2	In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4

PSS 3	In the last month, how often have you felt nervous and stressed?	0	1	2	3	4
PSS 4	In the last month, how often have you felt confident about your ability to handle your personal problems? (R)	4	3	2	1	0
PSS 5	In the last month, how often have you felt that things were going your way? (R)	4	3	2	1	0
PSS 6	In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
PSS 7	In the last month, how often have you been able to control irritations in your life? (R)	4	3	2	1	0
PSS 8	In the last month, how often have you felt that you were on top of things? (R)	4	3	2	1	0
PSS 9	In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
PSS 10	In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

PSS, perceived stress scale.

General Rules that were Used to Create the Novel PPS System

1. **Individual Tooth Prognosis:** The PPS system evaluates the periodontal prognosis of individual teeth only, disregarding patient-level prognosis, for simplicity and consistency.
2. **Selection of Parameters:** We chose 12 parameters that can be easily measured and recorded periodically by clinicians and hygienists (see Table 6). For instance, while clinical attachment loss (CAL) provides more accuracy than probing depth (PD), PD is included in the PPS for convenience. Similarly, %BL/root length replaces the complicated %BL/age parameter.
3. **Scoring System:** All parameter grades are quantified on a scale of 0 to 3 and summed to determine the final prognostic grade.
4. **Disease Progression Prediction:** The PPS system predicts not only tooth loss but also the progression of periodontal disease.
5. **Adaptability of PPS-12:** PPS-12, incorporating all 12 parameters, is recommended as the basic system. However, if certain parameters cannot be evaluated (e.g., stress survey or HbA1c measurement), prognosis can be estimated based on PPS-11 or PPS-10, respectively. Nonetheless, the essential 10 parameters of PPS-10 should always be evaluated as they are crucial for judging periodontal prognosis.
6. **Trackability and Research Compatibility:** The system allows for continuous tracking and comparison of prognosis changes during treatment or maintenance. Additionally, it facilitates retrospective and prospective research using standardized parameters.
7. **Periodic Re-evaluation:** The PPS system is planned for periodic re-evaluation (every 2 to 3 years) to assess and adjust the adequacy and accuracy of selected parameters. The goal is to align prognostic categories (good, fair, poor, questionable, and hopeless) with corresponding survival rates over specified timeframes.

These general rules aim to ensure the practicality, adaptability, and reliability of the novel PPS system, enhancing its usability for clinicians and researchers alike.

Table 6: 12 Parameters of the New PPS System

1.	Probing depth
2.	% BL/root length
3.	FI for multi-root or crown-root ratio for single-root
4.	Mobility
5.	Root proximity
6.	Combined lesion
7.	Smoking
8.	Alcohol
9.	Compliance
10.	Level of clinician
11.	Diabetes
12.	Stress

Analysis of the Prognostic Function of the 2017 Classification and Significance of the Novel PPS System

The 2017 classification stands out as an innovative system due to its dual role as a diagnostic and prognostic tool. By incorporating various risk and prognostic factors, it provides clinicians with valuable information for estimating the prognosis of periodontitis. However, its prognostic capabilities are limited to some extent, prompting the need for comparison with previous prognostic systems.

In our study, we analyzed the compatibility of McGuire's, Kwok and Caton's, and McGowan's prognostic systems with the 2017 classification. While McGuire's system demonstrated balanced matches for certain categories, others proved challenging to align due to ambiguous boundaries. Kwok and Caton's system showed promising compatibility, although further clinical validation is necessary. McGowan's system, on the other hand, exhibited poorer alignment with the 2017 classification, likely due to its reliance on a limited number of parameters.

The 2017 classification's unique feature lies in its dynamic nature, where both stage and grade can change based on therapy and maintenance outcomes. This adaptability enhances its prognostic function, allowing for continuous assessment and adjustment over time. However, limitations exist, particularly in distinguishing between severity and complexity in stage IV cases and the exclusion of combined lesions from the main classification.

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To address these shortcomings and offer a practical solution, we propose the Novel Periodontal Prognostic Scale (PPS) system. Developed based on seven guiding principles, the PPS system evaluates individual tooth prognosis using 10 to 12 easily measurable parameters. By adopting parameters such as alcohol consumption, compliance, combined lesions, clinician expertise, and stress, the PPS system enhances prognostic accuracy while maintaining simplicity.

We envision several potential roles for the PPS system in dentistry. Notably, it could minimize unnecessary extractions while facilitating prompt removal of teeth requiring immediate attention. Its simplicity and objectivity ensure consistency across clinicians and offer greater trust to patients. Moreover, its standardized approach fosters systematic research in periodontitis, enabling global comparison and assessment.

Through ongoing studies and parameter refinements, we anticipate the PPS system to evolve and remain updated with the latest research, further enhancing its prognostic capabilities and value in clinical practice and research alike.

Conclusions

The 2017 classification offers both diagnostic and limited prognostic capacities for assessing periodontitis. Through our analysis of various risk and prognostic factors within the classification, we sought to match each combination of stage and grade with corresponding categories from previous prognostic systems. Utilizing color gradient analysis, we visually confirmed that clinicians can roughly estimate periodontal prognosis by combining stage and grade. Among the three major prognostic systems—McGuire's, Kwok and Caton's, and McGowan's—we found that Kwok and Caton's system provided the best match.

McGuire's system exhibited limited correspondence with the 2017 classification, particularly in categorizing poor prognosis, while McGowan's system showed overall poor alignment despite its similarity in incorporating patient-related factors like smoking and diabetes, akin to the 2017 classification's reliance on risk factors.

However, due to the 2017 classification's primary focus as a diagnostic tool, its accuracy in predicting disease progression is limited. Thus, we propose a novel Periodontal Prognostic Scale (PPS) system, following seven guidelines we devised. It is essential to acknowledge that the novel system aims for convenience and simplicity rather than perfection, with the intent for future studies to verify its efficacy. Regular adjustments and improvements to parameters and system content, along with periodic error corrections, are crucial to enhancing the PPS system's practicality and usability for clinicians in real-world settings.

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