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Comparison of Two Periodontal Risk Profile Assessment Tools

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THESIS

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DEDICATION

This work is dedicated to my family, whom this work would have been impossible without their selfless love and support.

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Comparison of Two Periodontal Risk Profile Assessment Tools

Sally Sheng, DDS

ABSTRACT

Objective: The aim of this study is to compare two partially validated periodontal risk profile assessment tools designed to assess a patient's risk of developing periodontitis: the Periodontal Risk Assessment [PRA][17] and the Periodontal Risk Calculator [PRC][29]. The study will investigate the agreement or concordance of these two periodontal risk models when applied to the same study population.

Methods: A group of 100 subjects was assembled by random chart selection from patients seeking care at the UCSF Periodontology Clinic. Each subject's dental/medical history, clinical data, and radiographic data were reviewed, and the risk profile was generated according to both the PRA and the PRC models. The level of agreement between the risk profile as assessed by the PRA and the PRC models on the same study population was analyzed.

Results: Of the 100 subjects assessed, 14 low-risk, 49 medium-risk, and 37 high-risk cases were categorized by the PRA model, whereas the PRC model placed the same subjects in 13 low-risk, 16 medium-risk, and 71 high-risk groups. Statistical analysis demonstrated that there was only a weak level of agreement between the two models in identifying medium- and high-risk groups, while there was a very good level of agreement in identifying low-risk group. The PRC model identified more subjects as at high-risk of developing periodontitis in the future, while the PRA model identified a higher number of subjects as medium-risk group for future periodontal health breakdown.

Conclusions: The results suggest that risk scores generated for individual patients by different periodontal risk assessment models are highly variable. When used in periodontal clinical-decision making, choice of periodontal risk model could affect the risk assessment and may result in the misapplication of treatment for some patients. Long-term study on the validity and accuracy of current periodontal risk assessment models are needed to better achieve the goal of early identification of at-risk populations and formulation of proactive targeted interventions.

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INTRODUCTION

Chronic periodontitis is a destructive inflammatory multi-factorial disease initiated by microbial communities (*i.e.,* biofilms, dental plaques) that form on teeth. The development and progression of periodontitis are influenced by a wide variety of determinants, including subject-based characteristics (*e.g.,* genetic, systemic, social and behavioral factors) and local tooth-level factors (*e.g.,* microbial composition of dental plaque, crowded teeth, defective dental restorations).[28]

The risk for developing chronic periodontitis is not equal for all - the clinical extent and severity of the disease is influenced by individual risk.

Multiple studies have demonstrated that host factors play a major role in the patho-biology of chronic periodontitis and that risk varies greatly from one individual to another.[13,24,19,21.] Six hundred patients who had received periodontal therapy and periodontal maintenance care were followed over a course of 15 or more years and it was noted that patients differed markedly in post-treatment outcomes, such as tooth loss. In their patient population, some individuals referred to as the "extreme downhill group", lost from 10-23 teeth during the observation period, whereas other patients who they called the "well-maintained group", lost from 0 to 3 teeth.[13] Similar results were found in another private practice-based study of 100 treated and maintained patients.[24]

Variation of susceptibility to the disease and disease severity has also been noted among untreated population. Longitudinal studies of individuals with untreated periodontitis have confirmed that there are wide variations even among the untreated population in their risks for the progression of chronic periodontitis.[19,21.] Over a 2-year period in a Japanese population of 265 subjects with untreated periodontitis, it was found that 70% of the "loser" sites [*i.e.,* those

with ≥ 3mm of additional attachment loss] occurred in only 12% of the subjects.[19] Similar findings were found in a classic study on the natural history periodontal disease[21] where Sri Lankan tea laborers without any dental treatment were followed for 15 years. It was demonstrated that 8% and 81% of the population had rapid and moderate disease progression, respectively, while 11% showed no progression at all.[21]

Incorporation of Risk Assessment Procedures in Periodontal Therapy

With our increasing knowledge of the various risk factors associated with periodontitis, the implementation of a risk-assessment process for individual patients has become increasingly important in periodontal treatment planning. The American Academy of Periodontology has recommended that risk assessment should be part of every comprehensive dental and periodontal evaluation.[3] The practice of risk assessment allows dental care professionals to focus on early identification of at-risk populations and formulation of proactive targeted interventions.[8]

In 2008, the American Academy of Periodontology defined risk assessment as, "…the process by which qualitative or quantitative assessments are made of the likelihood for adverse events to occur as a result of exposure to specified health hazards or by the absence of beneficial influences.".[3] Traditional clinical parameters of periodontal diseases, such as probing depth, clinical attachment loss, and alveolar bone level, are cumulative measures of past disease and alone cannot accurately predict future disease activity.[32] Some clinicians often equate periodontal risk with the extent and severity of periodontal status.[32] That is, patients with little or no periodontal breakdown are assumed to be at low-risk for future disease, whereas patients presenting with more severe tissue destruction are considered to be at higher risk for future disease progression.[16] An individual can be at high risk for future periodontal breakdown, yet have little clinical or radiographic evidence of disease. An example would be a 27-year-old

patient who has uncontrolled diabetes and heavy tobacco use with only a few 5mm pockets in the posterior teeth, generalized mild clinical attachment loss, and no radiographic signs of crestal bone loss. While on the other hand, an individual can demonstrate signs of periodontal breakdown but be at low or moderate risk for future periodontal disease progression. An example would be a 70-year-old patient who has a history of treatment for generalized chronic severe periodontitis and for the past 5 years has been on a program of periodontal maintenance care. Although there may be radiographic evidence of severe crestal bone loss and clinical evidence of advanced clinical attachment loss with residual 5mm pockets, there has been no disease progression during the 5-year maintenance period. Identifying risk factors and undertaking measures that maximally reduce risks will allow clinicians to significantly reduce future disease incidence and progression by matching the intensity of intervention with the risk profile of the patient.[4] When levels of risk are not considered, treatment decisions based solely on disease extent and severity may result in over- or under-treatment of a significant proportion of patients.[32]

Definitions of Risk Factor, Risk Indicator, Risk Predictor

According to a Consensus Report of the 1996 World Workshop in Periodontics, a *risk factor* is, "…an environmental, behavioral, or biologic factor confirmed by temporal sequence, usually in longitudinal studies, which if present, directly increases the probability of a disease occurring, and if absent or removed, reduces that probability. Risk factors are part of the causal chain, or expose the host to the causal chain. Once disease occurs, removal of a risk factor may not result in a cure.".[11,5.] Longitudinal studies are necessary to demonstrate risk factors. A *risk indicator* is, "…a probable or putative risk factor, often detected in cross-sectional studies, that has not yet been confirmed by longitudinal studies.".[11,5.] A *risk predictor* is "…a characteristic

that is associated with elevated risk for disease but may not be a part of causal chain (*e.g.* tooth loss is a good predictor of future disease.)".[11,5.]

Numerous behavioral and environmental factors and their association with the prevalence and extent of periodontal disease have been investigated, however, only a few may be true risk factors possessing a causal relationship with the initiation and/or progression of attachment loss as identified by longitudinal studies. There is overwhelming evidence that both smoking and diabetes mellitus are important risk factors for periodontal tissue loss while more studies are needed to establish more accurately the contributions of other factors in the pathogenesis of periodontal diseases.[1] True identification of risk factors for disease, as defined above, should be based on prospective longitudinal studies but, most current evidence for the existence of possible risk factors for periodontal diseases are derived from cross-sectional studies.[1] However, prospective longitudinal studies are not always feasible and properly designed studies, such as the use of large representative surveys, cross-sectional, and retrospective case-control studies, can be used to investigate associations between different factors and the occurrence of periodontal diseases.[1] Current literature on periodontal risk assessment often incorrectly use the *risk factor* term when *risk indicator* or *risk predictor* would be more appropriate.[1] Incorporation of risk assessment tool may help the dental profession transition from a repair model to a wellness model of care, which over time may result in more uniform and accurate periodontal clinical decision-making, improved oral health, reduction in the need for complex therapy and health care costs.[29]

Risk Factors versus Prognostic Factors

In addition to assessing patients' risk of developing a disease, another important aspect of clinical practice is the assessment of the prognosis of the disease once it is present. While risk

factors deal with prediction of disease onset, prognostic factors deal with prediction of the course of existing disease.[27] Risk factors, if present, directly increases the probability of a disease occurring and if absent or removed, reduces the probability.[5] Prognostic factors, once the disease is present, directly affects the probability of a positive outcome of therapy rendered for the disease.[5] Periodontal disease is a complex multi-factorial disease and some factors may be considered to be both risk and prognostic factors (*e.g.,* smoking and diabetes), while others are simply prognostic factors (e.g., extent of presenting disease). Risk factors are part of the causal chain. Intervention on risk factors that lead to the onset of a disease will not necessarily lead to a favorable prognosis regarding the outcome once the disease occurs.[5]

Prognosis of periodontally involved teeth has been traditionally evaluated using the terms *good, fair, poor, questionable,* and *hopeless.*[25] Appendix I lists the guidelines for assignment to each prognostic group according to Mcguire. The ability to accurate predict the prognosis of periodontally involved teeth seemed to be limited to those initially deemed as having good prognosis, while prediction for all other prognostic groups are often incorrect.[25] The current method of assigning periodontal prognosis is often based on the clinician's expert opinion. The process is often complex and difficult as multiple factors are involved and each factor may be weighed differently depending on the clinician's knowledge, judgment, ability, and past experiences.[25] Appendix II provides a list of prognostic factors as reviewed by McGuire, but is by no means an exhaustive list.

Similar to risk assessment, an objective way of determining prognosis is needed. In a recent attempt in introducing a practical and evidence-based scoring index to objectively determine the prognosis of periodontally involved molars, Miller devised a scoring system incorporating the following factors: 1) patient's age, 2) number of furcation bone loss per tooth,

3) smoking, 4) pocket depth, 5) mobility, and 6) molar type.[27] This prognostic system shows promise and provides a statistically derived algorithm; however, long term validation study is still needed. The focus of this paper is on risk assessment as the subject of prognostic assessment for periodontally involved teeth itself is another complex topic worthy of a separate lengthy discussion. However, it is clear that the process of determining prognosis is a different but yet very similar process to risk assessment. Prognostic determination is aimed to predict the course of outcome once disease progression has been identified. The goal of risk assessment is to identify individuals at risk of developing the disease. Both processes are crucial in the creation of an individualized treatment plan and involve multiple factors with several of them being both prognostic and risk factors. Multiple systems exist for both processes, but a universally accepted objective method does not exist for neither at this time. Long term validation studies are needed on existing systems to evaluate their specificity and sensitivity and the accuracy of the available systems are uncertain for the majority of patients.

Current Objective Periodontal Risk Assessment Tools

Traditionally, clinical risk assessment consists of dental clinicians recognizing that factors enhancing risk are present in a given case, and making subjective judgments as to the magnitude of their role in the disease process based on their experience and professional knowledge. A study compared risk assessment by subjective expert clinician opinion with quantitative scores generated for the same subjects using a formal risk-assessment process (*i.e.*, the Periodontal Risk Calculator [PRC]).[34] They concluded that risk assessments based on subjective expert opinions of dentists and periodontists vary too greatly to be useful in clinical decision-making.[34] Expert clinicians varied greatly in evaluating risk and tended to underestimate the risk for the progression of periodontitis.[34]

Numerous risk assessment models have been introduced to help clinicians incorporate risk assessment into the diagnostic process. However, a universally accepted objective method does not exist at this time.[16] These models calculate risk based on an assessment of current and past findings that have been identified as contributing factors to risk for future disease. Relative risk values are then assigned based on individual model's algorithm of data analysis ranging from simple graphic representation to complex computer algorithm.[16] In an excellent review by Kye, currently available risk assessment models are reviewed and summarized in Table 1.[16]

Table 1. Characteristics of various risk assessment models. Modified from: Kye, et al. *J Evid Based Dent Pract.* 2012 Sep;12(3 Suppl):2-11.

Author(s)/Year	Risk Model	Risk Variables Evaluated	Notes
Page et al. (2002)[29]	Periodontal Risk Calculator (PRC)	11 Variables: - Age - Smoking status - Diabetes mellitus (DM) status - History of periodontal surgery - Bleeding on probing (BOP) - Furcation bone loss - Sub-gingival restorations - Vertical intrabony defects - Subgingival calculus - Pocket depth (PD) - Radiographic bone loss	Only the deepest PD and greatest bone loss per sextant are entered for PD and radiographic bone levels.
Lang & Tonetti (2003)[17]	Periodontal Risk Assessment (PRA)	6 Variables: - Full-mouth BOP % - PD ≥ 5mm - Tooth loss - Radiographic bone loss-to-age ratio	All sites of BOP and PD ≥ 5mm must be entered. Alveolar bone loss is limited to the most severe posterior site. Binary designation for "systemic

		- Diabetes status and relevant systemic conditions - Smoking status	and/or genetic conditions" category while 6 point scale is used for all other factors to construct a risk polygon.
Chandra (2007)[7]	Modified PRA	8 Variables: - Full-mouth BOP % - PD ≥ 5mm - Tooth loss - Clinical attachment loss (CAL)-to-age ratio - Smoking status - Diabetes Mellitus (DM) status - Systemic conditions - Psychosocial factors	DM is separated from systemic conditions. Clinical attachment is used instead of alveolar bone loss. Psychosocial factors added as a risk variable. 5 point score scale for each factor.
Leininger et al (2010)[18]	Periodontal Risk Assessment Diagram Surface (PRAS)	6 Variables: - Full-mouth BOP % - PD ≥ 5mm - Tooth loss - Radiographic bone loss-to-age ratio - Diabetes status and relevant systemic conditions - Smoking status	Identical to the PRA except, each variable has assigned score ranging from 0-10 along its vector in a hexagonal diagram. A risk score (PRAS) corresponding to the diagram surface, calculated with a trigonometric equation, was assigned to each patient. A score of 20 identified patients with a low-to-moderate periodontal risk. A score >20 identified patients with a high periodontal risk.
Lindskog et al. (2010)[20]	DentoRisk®	20 Variables: Systemic: Age in relation to history of chronic periodontitis, family history of chronic	Computerized risk assessment and prognostication program with unpublished proprietary algorithm.

		periodontitis, systemic disease and related diagnoses, result of skin provocation test, patient cooperation and disease awareness, socioeconomic status, smoking, clinician experience. Local: bacterial plaque (oral hygiene), endodontic pathology, furcation involvements, vertical intrabony defects, radiographic marginal bone levels, PD, BOP, marginal dental restorations, increased tooth mobility, missing teeth, abutment teeth, presence of purulence.	
Persson et al. (2003)[35]	Periodontal Pentagon Risk Diagram (PPRD)	6 Variables: - Full-mouth BOP % - PD ≥ 5mm - Tooth loss - Radiographic bone loss-to-age ratio - Diabetes status and relevant systemic conditions - Smoking status	Each risk factor has a corresponding vector score of 0-5, which is then used to calculate the surface area of the representing risk polygon. The surfaces area score is then used for risk assessment.
Trombelli *et al.*, (2009)[37]	University of Ferrara (UniFe)	5 Variables: - % of sites with BOP - # of sites PD ≥ 5mm - Radiographic bone loss-to-age ratio - Diabetes status - Smoking status	Each variable has a score ranging from 0-8 and the algebraic sum of each variable score is then used to assign patients to a risk category of 1-5.

DM = Diabetes mellitus
BOP = Bleeding on Probing
PD = Probing Depth
CAL = Clinical Attachment Loss

Periodontal Risk Calculator (PRC)

Page and colleagues (2002) introduced the Periodontal Risk Calculator (PRC) which evaluates 11 key risk parameters: 1) patient's age, 2) smoking, 3) diagnosis of diabetes, 4) history of periodontal surgery, 5) probing depth (PD), 6) bleeding on probing (BOP), 7) furcation involvement, 8) subgingival restorations, 9) root calculus, 10) radiographic bone height and the 11) presence of vertical bone lesions. The PRC is based on unpublished (proprietary), mathematically derived algorithms that assign relative weights to the various known risks that enhance patients' susceptibility to develop periodontitis. The PRC determines the patient's level of risk on a scale from 1 (lowest risk) to 5 (highest risk) and generates suggested treatment options to guide the clinician and patient toward a health-care strategy based on risk reduction. In addition to a risk score, PRC also generates a disease severity score of 1-100. No laboratory test results are required and all information needed for the assessment if information that is gathered during a routine periodontal examination.[29] The PRC is available for purchase on through the Previser™ company as part of the Oral Health Information Suite web-based computer program on http://www.previser.com/. (Previser™, Mount Vernon, WA)

Periodontal Risk Assessment (PRA) Model

The PRA model is based on a multi-factorial functional diagram composed of 6 vectors each representing a clinical, systemic, or environmental factors: 1) the level of infection (full-mouth bleeding scores); 2) the prevalence of residual periodontal pockets; 3) tooth loss; 4) an estimation of the loss of periodontal support in relation to the patient's age; 5) an evaluation of

the systemic conditions of the patient (*i.e.*, composite interleukin-1 (IL-1) gene polymorphism, or diabetes mellitus); and 6) environmental factors, such as tobacco use. The aggregate sum of these factors provides an individualized total risk profile for the patient. To predict the risk of recurrence of periodontitis in a previously treated population, patients are classified as belonging to one of the following risk categories: low- (all parameters on the six vectors fall within the low-risk categories or no more than one parameter in the moderate-risk category); moderate- (at least two parameters in the moderate category, but no more than one parameter in the high-risk category; or high- (at least two parameters in the high-risk category) PRA profile. In contrast to the Periodontal Risk Calculator (PRC), which is calculated at the onset of treatment, the PRA provides an assessment of risk for patients during the supportive, post-treatment phase, after active therapy has been completed.[16,17.] The PRA has been recommended for use on periodontal patients in maintenance to determine the frequency and extent of professional support necessary to maintain the attachment levels obtained following active therapy.[17] However, no explanations were given to why PRA cannot be used on periodontal patients seeking initial active therapy. Even though the creators of the PRC do not specify if it is targeted for patient population receiving initial active therapy or population in supportive therapy phase, on the website that clinicians can purchase the PRC program as part of the Oral Health Suite software, it is advertised that PRC can be used in combination with clinical observations to make treatment decision and used over time to assess treatment outcomes and monitor for deterioration. [36]

University of Ferrara (UniFe)

Trombelli and colleagues proposed a simplified risk assessment model (UniFe) using 5 key parameters: 1) smoking status; 2) diabetic status; 3) number of sites with PD $\geq$ 5 mm; 4) BOP score; and 5) a ratio of bone loss/age. A numeric value for each parameter was calculated,

based on its extent or severity. Each parameter has a score ranging from 0-8 and the algebraic sum of each parameter score is then used to assign patients to 1 of 5 risk categories:1(low), 2 (low-medium), 3 (medium), 4 (medium-high), or 5 (high).[37] Tables 2 and 3 summarize the five parameters and how parameter scores are assigned. Table 4 summarizes the assessment of risk from computation of all parameter scores.

Table 2 UniFe method: Generation of parameter scores. Modified from: Trombelli L, Farina R, Ferrari S, Pasetti P, Calura G. Comparison between two methods for periodontal risk assessment. Minerva Stomatol. 2009 Jun;58(6):277-87.

Parameter Score	Smoking Status	Diabetes Status	# of pockets with probing depth ≥5mm	% of sites with bleeding on probing
0	Never smoked	Non- diabetic	0-1	0-5%
1	Former smoker	N/A	2-4	6-16%
2	1-9 cigarettes/day	Controlled diabetic HgbA1c <7%	5-7	17-24%
3	10-19 cigarettes/day	N/A	8-10	25-36%
4	≥20 cigarettes/day	Poorly controlled diabetic ($HgbA_{1c}$ ≥7%)	>10	>36%

$HgbA_{1c}$ = Glycated hemoglobin

Table 3 UniFe method: Generation of parameter scores. From: Trombelli L, Farina R, Ferrari S, Pasetti P, Calura G. Comparison between two methods for periodontal risk assessment. Minerva Stomatol. 2009 Jun;58(6):277-87.

	# of teeth with radiographic bone loss ≥4mm					
	0	1-2	4-6	7-10	≥11	
Age (yrs)						
0-25	0	8	8	8	8	**Parameter Scores**
26-40	0	6	6	8	8	
41-50	0	4	4	6	8	
51-65	0	2	4	6	8	
≥66	0	0	2	4	6	

Table 4 UniFe method: Determination of risk score. From: Trombelli L, Farina R, Ferrari S, Pasetti P, Calura G. Comparison between two methods for periodontal risk assessment. Minerva Stomatol. 2009 Jun;58(6):277-87.

Risk Score	Sum of all five parameter scores
1 - Low Risk	0-2
2 - Low-Medium Risk	3-5
3 – Medium Risk	6-8
4 – Medium-High Risk	9-14
5 – High Risk	15-24

DentoRisk®

More recently, a web-based computerized risk assessment and prognostication program, DentoRisk®, has been developed to be (DentoRisk®, DentoSystem Inc, Salem, MA) to identify patients at risk of developing periodontitis and to generate prognosis for disease progression in

individuals diagnosed with periodontitis.[20] The model assesses 20 systemic and local risk variables, as listed in Table 5, to calculate the patient's overall risk score. This system assesses the most number of risk variables compared to other currently available risk assessment tools, it also incorporates individual inflammatory response as a risk factor with an in-office skin test for inflammatory reactivity to lipid A provocation called DentoTest® (DentoTest®, DentoSystem Inc, Salem, MA).[20] If an overall elevated risk to developing periodontitis is detected, a prognosis for annualized attachment loss for each individual tooth is then computed.[20] The formula used in calculating risk scores from the 20 risk variables is an unpublished proprietary algorithm. This system was only made commercially available in 2010, thus, long-term validation data is lacking and is not yet been widely used. There is currently only one validation study published by the system's inventors from a population of 183 patients treated in periodontal practices in the Stockholm area with an average of 3.8 years of follow-up.[20] The goal of the system is to provide both the patient and the clinician with a reliable, consistent, and objective way to assess risk of disease development and future prognosis in making sound treatment planning decisions.[20]

Table 5 Periodontitis risk predictors integrated by DentoRisk® algorithm. Modified from: Lindskog, et al. Validation of an algorithm for chronic periodontitis risk assessment and prognostication: risk predictors, explanatory values, measures of quality, and clinical use. J Periodontol. 2010 Apr;81(4):584-93.

Systemic Predictors	Recorded As	Local Predictors	Recorded As
Age in relation to history of chronic periodontitis	Unclear	Bacterial plaque (oral hygiene)	Unclear
Family history of chronic periodontitis	Yes or No	Endodontic pathology	Yes or No
Systemic disease(s)	Yes or No	Furcation involvement	Yes or No
Skin provocation test (DentoTest®) to assess the patient's inflammatory reactivity	Negative or Positive	Angular bony destruction	Yes or No
Patient cooperation and disease awareness	None, Some, or High	Radiographic alveolar bone loss	Yes or No

Socioeconomic status	1) Negative stress including nutritional decencies, obesity, alcohol abuse, and other stress-related factors 2) Economic problems 3) Combination	Periodontal probing depth	Unclear
Smoking habits	No, Past Use (stopped <5 yrs ago and had smoked >10 cigarettes/ day), or Yes: - <10 cigarettes/day - 10-20 cigarettes/day - >20 cigarettes/day	Periodontal bleeding on probing	Yes or No
The therapist's experience with periodontal care	None/Negligible, Some, or Extensive (by clinician self-assessment)	Marginal dental restorations	Yes or No
		Increased tooth mobility	Yes or No

Validation Studies

The accuracy and validity of risk scores calculated using the PRC as predictors of periodontal status had been tested on 523 patients recruited from the VA Dental Longitudinal Study throughout a 15-year observational period.[29] Statistically significant positive associations were found between risk scores and 1) alveolar bone loss from baseline, 2) increase in percentage of sites with alveolar bone loss, and 3) number of tooth loss. [29] Groups with higher risk scores were noted to have higher number of tooth loss, higher number of sites with bone loss, and higher percentage of bone loss as compared to baseline at the end of the 15 year observation.[29] Even though the PRC demonstrated ability to predict risk of periodontal deterioration as measured by change in alveolar bone status and tooth loss, it should be noted that majority of the subjects reported that they received one or less dental treatment during the

course of the study, hence, the findings may be relevant only to untreated populations and the effects of treatment on the outcome of the risk predictions is unknown.[29] Comparable longitudinal studies of PRC on subjects who have had periodontal therapy is still needed. Use of the PRC risk assessment and its suggested treatment options over time may be expected to result in more uniform decision-making about periodontal disease: a reduction in disease incidence, improved oral health and a significant reduction in the need for complex periodontal treatment and the cost of care.[29,30,32.] In a subsequent study using the same population, it was found that tooth loss was more precisely and accurately predicted by the combination of risk and severity scores calculated by the PRC program than by either score alone.[22]

Comparing the Unife and the PRC risk models in a blind retrospective study of 107 randomly selected patients seeking periodontal treatment, an agreement was demonstrated between the two models in approximately 75% of the patients.[37] However, long-term, longitudinal studies are still needed to further validate the UniFe model.[37]

A statistically significant association between high periodontal risk as assigned by the PRA at the start of supportive periodontal therapy and future tooth loss was demonstrated in a study.[9] In his study of 100 patients who were in supportive periodontal therapy for 10 years ± 6 months, patients assigned to the high-risk group according to the PRA after accomplishment of prescribed periodontal therapy suffered from a higher rate of tooth loss than the other risk groups.[9]

Comparable finding was found with another retrospective study on 160 patients who completed prescribed periodontal therapy and 9.5 +/- 4.5 years of supportive periodontal therapy. Patients with a high-risk profile, as calculated with PRA, were more prone to recurrence of periodontitis and to tooth loss than patients with a moderate- or a low-risk profile.[23]

The host inflammatory response to the bacterial challenge may be accentuated by certain gene polymorphisms and influence an individual's susceptibility to periodontitis.[14] Specific IL-1 genotype polymorphism have been suggested to be associated with an exaggerated local inflammatory response with more robust IL-1 secretion leading to increased tissue destruction.[10,15.]

A study following patients, who were in 4 years of supportive periodontal therapy after completion of definitive periodontal treatment, suggested that PRA may be a useful approach for identifying patients who may respond less favorably to maintenance therapy.[35] At the end of 4 year supportive periodontal therapy, IL-1–negative patients, demonstrated reduced PRA risk scores indicating a lower risk of disease progression, whereas scores increased for IL-1–positive patients, indicating an higher risk of future periodontal breakdown.[35]

Several modified versions of the original PRA have been proposed in the literature. It has been suggested that one reason why many modified versions of the PRA are available but not for the PRC could be that compared to the PRA, PRC is "too complicated for the practitioner to implement in clinical practice"[16] and that compared to the PRC, the PRA-related model had the ease of interpretation, because visual inspection of the risk diagram allows the clinician to rapidly place patients into low-, medium-, and high-risk categories.[7]

Comparative Evaluation between Two Methods for Periodontal Risk Assessment.

Many studies have compared the original PRA model to modified versions of the PRA model. However, to date, no studies have compared the PRA model to the PRC model. The reason for this might be that the PRA is intended as a risk model to be utilized during the supportive maintenance phase of treatment after definitive periodontal therapy, and the PRC is intended to be used in the initial treatment-planning phase with suggested treatment options for

each risk category. Another potential difficulty in comparing the two risk models is that the PRA is a graphic representation with a risk polygon categorized as low, medium, or high risk. The PRC, however, provides a 1-5 point scale of numeric risk score along with a 1-100 numeric score of disease severity.

With the PRA and the PRC being the two most commonly utilized and most studied periodontal risk models, the focused question of interest is whether or not these two different risk models are comparable. The null hypothesis of the study is that when applied to the same study population, these two periodontal risk models should have no statistically significant difference in the distribution of patients assigned to the various risk categories.

Aims/Objectives

The aims of this study were to: 1) compare two partially validated periodontal risk profile assessment tools, the Periodontal Risk Assessment [PRA][17] and the Periodontal Risk Calculator [PRC][29] and 2) determine the agreement or concordance of these two periodontal risk models when applied to the same study population.

MATERIALS AND METHODS

Study Population

The study was approved by the University of California, San Francisco Committee on Human Research , which is a is a committee operating under federal, state, and institutional regulations that reviews research involving human subjects to ensure the ethical and equitable treatment of those subjects. The study was approved under category 4 exempt status as the study involved collection and study of existing data and the information was recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. Furthermore, the study did not include children, prisoners, or in-patients.

Data for risk assessment was retrospectively derived from a random chart selection from existing patient records of the UCSF Postgraduate and Faculty Periodontology Clinic. A print-out list of all patients seen in the UCSF Periodontology Clinic in the past 10 years (from 2003-2013) was generated and each chart was assigned a number with 0 being the first chart on the list and the last chart on the list was the last number assigned. For example, if there were a total of 963 patients seen in the UCSF Periodontology Clinic from 2003-2013, then the first chart on the list was #0 and the last chart on the list was #963. A random number generator program, the *Random Integer Generator* from http://www.random.org/integers/, was used to select charts randomly from the list. Each patient record selected was considered eligible for inclusion in the study according to the following inclusion criteria:

- no more than 12 missing teeth (excluding third molars)
- availability of dental/medical history, clinical data, and radiographic data necessary for risk assessment according to both the PRA and the PRC methods.

The chart review process continued until 100 eligible patient records were identified. No patient identifiers were recorded in the data collection. After recording of the patient parameters, a periodontal risk profile was generated for each patient by both the PRA and the PRC model. Table 6 lists the parameter data collected by the PRA and PRC risk models

Table 6. Patient Parameters Evaluated by the PRA and PRC Risk Assessment Models.

	PRA	PRC
Patient Age	Recorded	Recorded
Smoking	Former smoker (if quit for ≥5 years); Occasional Smoker (≤10 cigs/day);	Never smoked; Former smoker (quit for <10 yrs OR ≥10 yrs); Current Smoker (≥10cig/day, <20cigs/day,

	Smoker (≤20 cigs/day); Heavy Smoker (> 20 cigs/day)	OR ≥20 cigs/day)
Diabetic status (per patient self-report)	Yes or No	Non-diabetic; Good diabetic control (HbA1c <6.5% or fasting glucose 90-104mg/dL); Fair diabetic control (HbA1c 6.5-7.5% or fasting glucose 105-130mg/dL); Poor diabetic control (HbA1c >7.5% or fasting glucose >130mg/dL)
History of periodontal surgery	Not Collected	Yes or No
Probing Depth	Number of sites with probing depth ≥5mm out of all existing dentition	One Deepest Site Per Sextant recorded as <5mm; 5-7mm; >7mm; OR No teeth
Bleeding on probing	Number of sites positive for bleeding on probing out of all existing dentition	Yes or No recorded for each sextant regardless of number of sites
Furcation bone loss involvement	Not recorded	Yes or No
Presence of restorations poor contours and/or overhang	Not recorded	Yes or No
Presence of root	Not recorded	Yes or No

calculus		
Alveolar bone loss	Measured radiographically at the most advanced site in the whole mouth and recorded as percentage of bone loss. In periapical radiographs, the % alveolar bone loss is compared with the distance 1mm apical from the cemento-enamel junction to the root apex. In Bitewing radiographs, % alveolar bone loss is calculated as 10% per 1mm distance apical from the cemento-enamel junction.	Measured radiographically at the most advanced site per sextant and recorded as : <2mm, 2-4mm, >4mm, OR No teeth
Presence of vertical bone lesions	Not recorded	Yes or No
Number of missing teeth	Recorded	Not recorded
Number of sites per tooth / implant used to record perio charting	Recorded as each site with bleeding on probing and/or probing depth ≥5mm are recorded and percentage out of the whole dentition calculated	Not recorded. Does not look at individual site and calculate percentage out of whole dentition for bleeding on probing and deep probing depth. Looked only at most severe site per sextant for probing depth and bleeding on probing is recorded as yes or no per sextant regardless of the number of sites involved.
Dental care frequency -– compliance	Not recorded	Compliant or Non-compliant
Oral hygiene improvement	Not recorded	Yes or No

needed		
History of scaling and root planning	Not recorded	Yes or No

The Periodontal Risk Assessment (PRA) model

PRA model as described by Lang and Tonetti[17] was utilized in assessing periodontal risk profiles for each subject. The PRA model assigns low, moderate, or high risk profiles based on the following six parameters:

1.Percentage of sites with bleeding on probing

2.Percentage of sites with probing depth ≥ 5mm.

3. Number of lost teeth from a total of 28 teeth (third molars excluded)

4. Alveolar bone loss**]** in relation to the patient's age - Measured radiographically at the most advanced site in the whole mouth and recorded as percentage of bone loss.

In periapical radiographs, the percentage of alveolar bone loss is compared with the distance 1mm apical from the cemento-enamel junction to the root apex.

In bitewing radiographs, percentage of alveolar bone loss is calculated as 10% per 1mm distance apical from the cemento-enamel junction.

5. Systemic and genetic conditions –The PRA instruction on this parameter was to indicate positive for this parameter if the patient has diabetes, IL-1 polymorphism, or stress. Diabetes management status was not considered by PRA program, only a yes or no data was collected, Il-1 polymorphism testing was not part of the routine periodontal examination and none of the 100 patients had records of their IL-1 polymorphism status. One patient's chart was noted for stress related to recent passing of family member. It is more likely that the absence of stress noted in the charts was due to poor data collection/recording than the fact that the other 99 patients had no

stress life events. Systemic conditions, such as hematological disorder/leukemia, diabetes mellitus, immune system disorders, can all have modifying effect on periodontal health of an individual. Of the 100 qualifying subjects, two were noted be HIV positive, but did not have documentation of the status of HIV management (i.e., viral load, and CD4 T-cell count). Other than diabetes mellitus, no other genetic or systemic diseases were noted in the charts of these 100 subjects.

6. Smoking Status - Former smoker (if quitted for ≥5 years); Occasional Smoker (≤10 cigs/day); Smoker (≤20 cigs/day); Heavy Smoker (> 20 cigs/day)

Each parameter forms an axis on a polygonal diagram with assigned critical values that create a five nesting polygons. The area of relatively low risk is found within the inner two polygons, while the area of moderate risk is found between the middle two polygons, and the area of high risk is found outside the periphery of the fourth ring in bold. Table 7 summarizes the six parameters and associated critical values. Figure 1 is an example of the functional polygonal diagram.[17]

Figure 1. Functional diagram to evaluate the patient's risk for recurrence of periodontitis. From: Lang NP, Tonetti MS. Periodontal risk assessment (PRA) for patients in supportive periodontal therapy (SPT). Oral Health Prev Dent. 2003;1(1):7-16

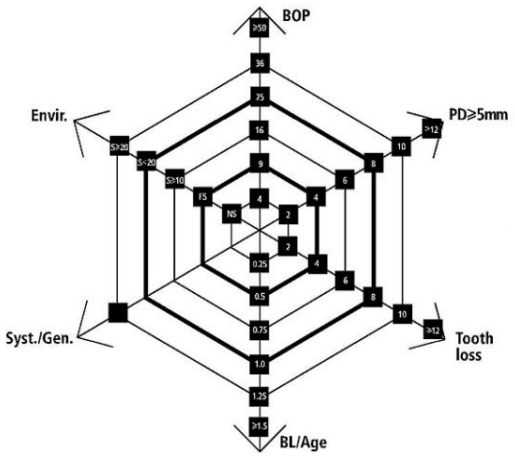


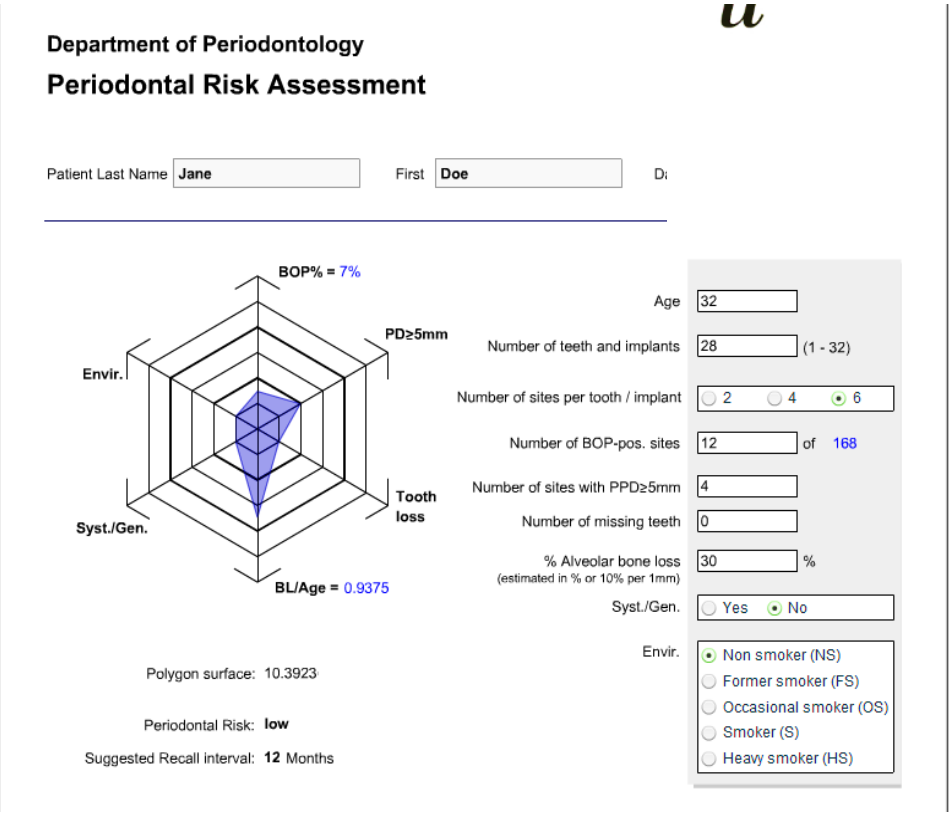
Table 7. PRA parameters and associated critical values.

Parameter	Critical value points on the polygonal diagram					
Full-mouth % of sites with bleeding on probing	≤4%	≤9%	≤16%	≤25%	≤36%	≥50%
Prevalence of residual pockets ≥ 5 mm	≤2%	≤4%	≤6%	≤8%	≤10%	≥12%
Number of lost tooth (not including third molars)	≤2	≤4	≤6	≤8	≤10	≥12
Alveolar bone loss in relation to age	≤0.25	≤0.5	≤0.75	≤1	≤1.25	≥1.5
Systemic and genetic conditions	Absent				Present	
Environmental Factors/Smoking	Non-smoker	Former smoker	≥10 cigs/day	<20 cigs/day	≥20 cigs/day	

Each vector represents one risk factor or indicator with an area of relatively low risk, an area of moderate risk and an area of high risk for disease progression. All factors have to be evaluated together and hence, the area of relatively low risk is found within the center circle of the polygon, while the area of high risk is found outside the periphery of the second ring in bold. Between the two rings in bold, there is the area of moderate risk.

To calculate the surface area encompassed by the PRA risk assessment, a web-based program developed by the University of Bern with free open access to the public from http://www.perio-tools.com/pra/en/ was used. After putting in data for each of the parameters, the program generated a risk profile and polygon surface area. Figure 2 below is an example.

Fig. 2 Example of PRA risk assessment profile and surface area derived from web based program on http://www.perio-tools.com/pra/en/



The Periodontal Risk Calculator

The PRC risk profile for each patient was generated by the online Oral Health Suite® program that was available commercially on Previser's website (www.previser.com). The Oral Health Suite® program is commercially available web-based software that claims to guide the clinicians and patients toward a risk reduction therapy individually tailored by assessing caries and periodontal risk profiles. Previser is the company that markets the Oral Health Information Suite® commercially to dental professionals. The program was purchased for this study by a university grant at reduced cost for academic research purpose.

After information is collected on the following parameters, the PRC model generates a risk score from 1 (lowest risk) to 5 (highest risk) and a disease severity score from 1 to 100 for each patient. Figure 3 is a sample patient report of the PRC risk model.

1. Patient's age

2. Smoking - Never smoked; Former smoker (quit for <10 yrs OR ≥10 yrs); Current Smoker (≥10cig/day, <20cigs/day, OR ≥20 cigs/day).

3. Diagnosis of diabetes – Non-diabetic; Good diabetic control (HbA1c <6.5% or fasting glucose 90-104mg/dL); Fair diabetic control (HbA1c 6.5-7.5% or fasting glucose 105-130mg/dL); Poor diabetic control (HbA1c >7.5% or fasting glucose >130mg/dL).

4. History of periodontal surgery – Yes or No answers were reported from review of chart notes, procedure log, billing transaction history, and patients' self-reported history as recorded in the charts.

5. Probing depth - One deepest site per sextant recorded as <5mm; 5-7mm; >7mm; or No teeth present at all.

6. Bleeding on probing- Yes or No recorded for each sextant; PRC does not collect information on number of sites involved.

7. Furcation involvement - Yes or No recorded; PRC does not collect information on number of sites involved and degree of furcation bone loss. Utilizing the classification system proposed by Hamp-Lindhe-Nyman[12], UCSF periodontal examination recorded furcation bone loss involvement as 0 (no bone loss detected), class I (Furcation defect is < 3 mm in its horizontal probing depth.), II (Furcation defect is ≥3 mm in depth but not a through-and-through lesion. There is still some inter-radicular bone attached to the dome of the furcation. The furcation defect is often described as a cul-de-sac.), III (Furcation defect encompassing the entire width of

the tooth in that no bone is attached to the dome of the furcation. The defect is often described as through-and-through.). Class I, II, and III furcation involvements noted in the charts were converted to a positive answers and class 0's were entered as negative answers for presence of furcation bone loss in the PRC. Radiographs were also examined and inter-radicular radiolucencies were recorded as positive for furcation bone loss involvement.

8. Subgingival restorations – Yes or No answers as determined by examination of full-mouth series of radiographs and chart notes for clinically detected subgingival restorations not shown radiographically.

9. Root calculus - Yes or No answers as determined by examination of full-mouth series of radiographs and chart notes for clinically detected root calculus not shown radiographically.

10. Radiographic bone height - Measured radiographically at the most advanced site per sextant and recorded as : <2mm, 2-4mm, >4mm, OR no teeth at all.

11. Presence of vertical bone lesions – Yes or No answers as determined radiographically. The PRC did not provided instruction or guidelines as to how assessment should be done. For this study, the vertical lesions were assessed radiographically by the method published by Persson. An imaginary line was drawn from the interproximal cementoenamel junctions of adjacent teeth (if interproximal restorations are present the apical margin of the restoration will be used instead) and a second imaginary line was drawn at the most coronal aspect of alveolar crest. If the angle formed by the intersection of these two lines is greater than 45 degrees then a vertical defect is considered present.[33]

Figure 3. Sample Patient Report of the PRC Risk Model.

http://www.previser.com/documents/Perio-Report-Sample-2014.pdf

Characteristics of Health and Low Risk	Your Characteristics of Health and Low Risk	Analysis
Bleeding during exam or flossing	Bleeding during exam	Bacteria are causing an infection, which can worsen your disease state
Bone height	Moderate bone loss	Significant bone loss has occurred and additional bone loss could cause you to have a tooth extracted
Calculus in the pockets	Tartar below the gumline	Calculus is a major cause of disease state worsening
Defective restorations	A filling or crown does not fit well	This condition traps bacteria, which cause gum disease and decay
Diabetes	Not diabetic	Best possible condition
Furcations	Bone loss in a furcation	Cleaning the bacteria from these sites might not be possible leading to a worse condition
Oral hygiene	Too much bacterial plaque	Preventing new disease is extremely difficult and treatment is most likely to fail
Pocket depth	Deepest pocket is 5-7 mm	Bacteria is beyond the reach of tooth-brush and floss and possibly the dentist's tools
Smoking	Smokes 10 or more cigarettes per day	Smoking this much complicates treatment and increases the likelihood of failure
Vertical bone lesions	X-rays show bone level is uneven	Usually consistent with deep pockets that worsen

Data Analysis

Statistical analysis was conducted to explore the following:

- Mean and standard deviation (SD) of patients' parameters calculated and analyzed.
- Risk distribution of the study population according to the two risk models.
- Cohen *k*-statistics to quantify the level of agreement between the PRC and the PRA models.

All patient data and the generated PRA and PRC risk scores were entered into a computer database and the averages and standard deviations for patient demographics were calculated using Microsoft Excel software program. (Excel, Microsoft Office 2007, Microsoft, Redmond, WA, USA)

To investigate the agreement between the PRA and PRC risk assessment models, Cohen's kappa statistical test was employed. Cohen's kappa coefficient is a statistical measure of inter-rater agreement or inter-risk model agreement for categorical data.[6] Complete agreement would correspond to k = 1, while when k = 0, it suggests that the level of agreement is no better than random chance. A negative value of kappa would suggest the level of agreement is worse than random chance and indicates a propensity of raters avoiding assignments made by other raters.[26] While there have been numerous guidelines proposed to interpret the magnitude of agreement for k values, the most common guideline utilized in medical research is the guideline proposed by Altman, where k< 0.20 - poor agreement; k= 0.20-0.40 - fair agreement; k= 0.40-0.60 - moderate agreement; k= 0.60-0.80 - good agreement; and k= 0.80-1.00 - very good agreement.[2] However, it should be noted that the Altman guideline and all other guidelines proposed for the interpretation of the magnitude of agreement for kappa value are all somewhat arbitrary in that

all do not have clear criteria definition for the term used to describe the magnitude. For example, the difference between good versus very good agreement is not clearly defined.

Cohen's kappa statistic was calculated using the following formula:

$$k = \frac{P(A) - P(E)}{1 - P(E)}$$

P(A) is the proportion of times the raters agree, and P(E) is the proportion of times the raters are expected to agree by chance alone.[6]

RESULTS

The group consisted of 53% males and 47% females with a mean age of 56.38 ± 13.61 years and an average of 24.93 ± 2.89 teeth (out of 28 teeth total). Eleven percent of the subjects were former smokers with 3/11 having less than 10 years of cessation period; 15% were current smokers with 7/15 of those subjects smoking less than 10 cigarettes a day. Seventy-four percent of the subjects had never smoked. Fifteen percent of the study population self-reported as being diagnosed with diabetes mellitus. One-third of the diabetic patients had good blood sugar control, 1/3 had fair control, and the remaining 1/3 had poor control per the PRC guideline. The PRC guideline classified diabetic control into 4 categories: Good diabetic control (HbA1c <6.5% or fasting glucose 90-104mg/dL); fair diabetic control (HbA1c 6.5-7.5% or fasting glucose 105-130mg/dL); and poor diabetic control (HbA1c >7.5% or fasting glucose >130mg/dL).

Twenty-five percent of the study population had furcation involvement; average bleeding on probing was 33.53 (± 31.02) sites, and had an average 15.08 (± 16.02) sites with probing depth ≥5mm. Eighty-eight percent of the study population had a history of scaling and root planning treatment, and 35% had received surgical periodontal therapy. Patients whose charts indicated periodontal maintenance visits no more than two months beyond the recommended recall

interval noted in their charts were identified as compliant while patients who had lapse longer than two months were noted as non-compliant with their periodontal maintenance schedules. Fifty-three percent of the study population was compliant with dental recall schedules as recommended by their dental care providers, while 47% of the subjects did not demonstrate such compliance. Table 8 illustrates the characteristics of the study population.

Table 8: Patient Demographics

Male	53%
Average Age	56.38 yrs (± 13.61)
Average # of teeth present	24.93 (± 2.89)
Former Smoker	11%
Current Smoker	15%
Diabetic	15%
Furcation bone loss	25%
Average number of sites with bleeding on probing	33.53 sites (± 31.02)
Average number of sites with probing depth ≥5mm	15.08 sites (± 16.02)
History of scaling and root planning	88%
History of surgical periodontal therapy	35%
Compliant w/ dental recall schedule	53%

Fourteen low-risk cases, 49 medium-risk cases, and 37 high risks cases were identified by the PRA model, whereas 13 low-risk cases, 16 medium-risk cases, and 71 high-risk cases were identified by the PRC model. The number of low-risk cases identified by the PRA and the PRC models were similar (14% and 13%, respectively), but the PRC model identified more cases as high-risk while the PRA model identified more cases as medium-risk. Figure 4 illustrates the

distribution of risk assessment with the PRA and PRC models on the 100 subjects. As noted in Table 9, Cohen *k*-statistics for the high-risk group was 0.39 and 0.26 for the medium-risk group, suggesting only a moderate level of agreement, per the guidelines proposed by Altman, between the two risk assessment methods in identifying the high- and medium-risk cases. According to the Altman guidelines, there was a good level of agreement for the low-risk group between the two risk models as evident with Cohen *k*-statistics of 0.96.

Figure 4. Distribution of high-, medium-, and low risk cases according to the Periodontal Risk Assessment (PRA) and the Periodontal Risk Calculator (PRC).

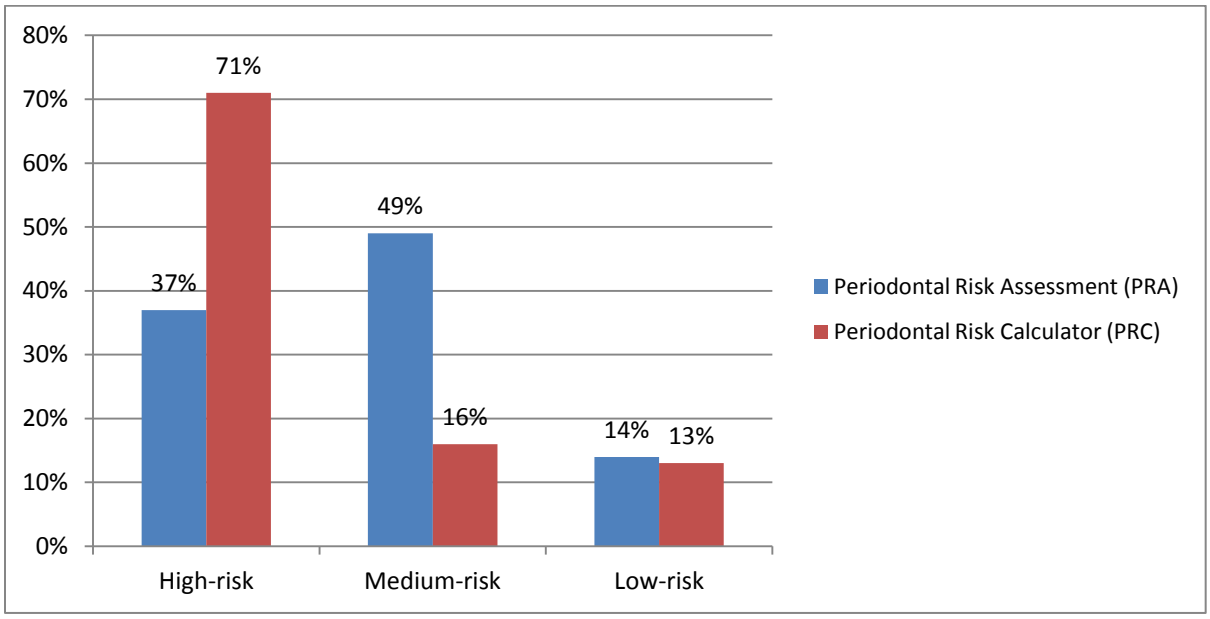


Table 9. Level of agreement between the PRC and the PRA risk assessment models

Risk Categories	Cohen *k* value	Level of Agreement*
High-risk	0.39	Fair
Medium-risk	0.26	Fair
Low-risk	0.96	Good

* Poor agreement < 0.20; Fair agreement = 0.20-0.40; Moderate agreement = 0.40-0.60; Good agreement = 0.60-0.80; Very good agreement = 0.80-1.00. Altman DG. Practical Statistics for Medical Research. (1991) London England: Chapman and Hall.

DISCUSSION

To the researcher's best knowledge, no comparison study has been done comparing the PRA risk assessment model to the PRC model to date. This study was the first to compare these two risk assessment models. Random selection from a large patient pool of a university based postgraduate periodontal clinic provided a diverse subject sample with detailed extensive treatment records available. One could argue though that there is an inherent biased sampling. For example, these are all patients referred to the Graduate Periodontal clinic at UCSF by private general dentists, private periodontists, and UCSF pre-doctoral clinic and could represent a group of patients already at higher risk for periodontal disease progression than the general population. Or that they may represent a group of patients that did not previously have had proper dental care due to various factors (i.e., financial limitation, busy schedule, low dental awareness, fear of dentist, etc.) leading to their need for periodontal specialty care at a university based postgraduate periodontal clinic. Future studies could minimize such potential sampling bias by recruiting subjects from both periodontists and general practitioners and university based and private offices. However, such subject sampling would require complex multi-office coordination and manpower.

This study identified 14% low-risk, 49% medium-risk, and 37% high risks cases with the PRA risk model. Comparing to a previous study on 26 patients with PRA that identified 30.8% low-risk, 26.9% medium-risk , and 42.3% high-risk cases, this study had larger proportion of subjects at higher risk.[7] With the PRC risk model, this study identified 13% low-risk, 16% medium-risk, and 71% high risks cases; whereas a previous study on 523 VA subjects with PRC

identified 20.3% low-risk, 36.9% medium-risk, and 43.8% high risks cases.[29] Like the PRA, this study population included higher proportion of higher risk patients compared to previous PRC study. This observation brings up the potential of sampling bias previously discussed.

In addition to the potential sampling bias, in future studies, data collection and data analysis should be done by separate researchers who are properly blinded. All the study data was collected, reviewed, and analyzed by a single investigator who was not blinded to the purpose of this study. Even though reproducibility was demonstrated with repeated data sampling, one cannot rule out the possibility of single researcher biases. In the course of data collection, patient identifiers were removed, however, the researcher had recognized patients that she had provided periodontal treatment previously from radiographs. This could have potentially led to the researcher favoring a more positive evaluation of the data with these patients.

The implementation of a risk-assessment process for individual patients has become increasingly important in periodontal treatment planning as the risk for developing periodontal disease is not equal for all subjects, and the clinical extent and severity of the disease is influenced by individual risk. The practice of risk assessment allows dental care professionals to focus on early identification of at-risk populations and formulation of proactive targeted interventions[8,34] suggested that an objective risk assessment tool is more useful in clinical decision-making as traditional subjective clinician opinion-varied greatly in evaluating risk and tended to underestimate the risk for the progression of periodontitis.

Numerous periodontal risk assessment models have been introduced to help clinicians incorporate risk assessment into the diagnostic process. The purpose of this study was to investigate the level of agreement between two popular and partially validated periodontal risk

profile assessment tools: the Periodontal Risk Assessment [PRA][17] and the Periodontal Risk Calculator [PRC].[29]

The hypothesis was that the two different risk assessment models should have no statistical difference in the assignment of risk profiles when applied to the same population. This study showed that when applied to the same population, the PRA model identified more medium-risk cases whereas the PRC model identified a higher percentage of high-risk cases. Both models identified a similar percentage of low-risk cases. The two models differ in that the PRA assesses risk based on cumulative and retrospective data intended as a risk model to be utilized during supportive maintenance phase of treatment after active treatment, and the PRC assesses risk prospectively intended to be used in the initial treatment planning phase.

The PRA evaluated six parameters while the PRC evaluated 11 parameters. It may be possible that with the additional parameters, the PRC evaluated risk factors not incorporated in the PRA model resulting in a higher percentage of the high-risk group being identified. Compared to the PRC, the PRA model does not collect information on history of periodontal surgery, history of scaling/root planning, oral hygiene level, level of compliance to dental recalls, presence of vertical bone lesions, presence of furcation bone loss, presence of root calculus, and presence of defective dental restorations. One explanation why those factors are not included in the PRA assessment could be that since the PRA is intended for use during the supportive maintenance phase of the therapy, the assumption is that correctable risk factors were already addressed during the active therapy phase.

Another possible reason that the PRC model categorized more subjects as high risk compared to the PRA could be the algorithm over-calculates the effect of sites with bleeding on probing and deep probing depth. The PRA records total number of sites positive for bleeding on

probing and with probing depth ≥5mm out of all existing dentition. The PRC breaks down probing depth data further by categories of <5mm; 5-7mm; >7mm; or no teeth at all, however, only records the deepest affected site for each sextant and does not take into account the number of sites affected. Bleeding of probing is recorded as present or absent for each sextant by the PRC and like the probing depth, the number of sites affected is not evaluated. With the PRC, an individual with one positive site for bleeding on probing in a sextant would be treated the same as an individual who has all sites in a sextant positive for bleeding on probing.

Diabetes status is also weighed differently between the two risk models. The PRA risk model considers diabetes as simply a yes or no response and does not take into account the level of diabetes control like the PRC model. One patient with poor diabetic control in the study was categorized as high risk by the PRC while the PRA assigned a medium risk status.

This study did not include long-term follow-up data of patients and only utilize patient data at a single time point. With such a large disagreement in the assignment of medium- and high-risk groups between the two models, it will be interesting for future study to evaluate the long-term predictive value of each model. Long-term data will allow evaluation to see if PRA or PRC more accurately predict future periodontal breakdown and/or tooth loss. The limited data from this study was only able to demonstrate the lack of agreement between the two models in assessing medium- and high-risk groups and no conclusion can be drawn as to which model will result in less over-/under-treatment and can more accurately predict future periodontal breakdown.

A future area of research is if presentation of a formal periodontal risk assessment report will affect patients' acceptance and attitude toward periodontal therapy recommended, and if it will increase compliance with regular recommended dental recall schedule. The compliance to

recommended dental recall rate noted in our study population was 53%, which was in line with Wilson's finding that patients in university-based programs have a dropout rate (non-compliance) of 11% to 45%.[38]

The high level of agreement between the two models in identifying low-risk group appears to reflect the clinical reality that the low risk group patients are easily identified. Clinicians usually have little difficulty in assessing patients who are at the opposite ends of the risk spectrum. Low-risk groups and extreme high-risk group patients are usually readily identified while the patients in the middle of the risk spectrum are more difficult to assess their level of risk. The low level of agreement between the two models in assessing medium- and high-risk groups indicates a need to have long-term study of currently available periodontal risk assessment tools to better examine the validity and accuracy of these risk assessment models.

The use of a risk assessment tool over time may result in more uniform and accurate periodontal clinical decision making, improved oral health, reduction in the need for complex therapy, and reduction in health care costs.[34] However, without proper long-term validation study, it is currently difficult for clinicians to make a decision on which of the available periodontal risk assessment tools to use. Often times, the decision may not be based on the accuracy and validity of the risk models, but rather the ease of use, amount of time, and amount of patient parameter data required.

CONCLUSIONS

The data demonstrated that level of agreement between the PRA and the PRC risk models in assessing subjects' risk of experiencing periodontal disease was unexpectedly low among the medium- and high-risk groups. The lack of agreement was due, in part; to the underestimation of

risk by the PRA model relative to the PRC as reflected by their assignment of fewer subjects to high-risk group and more to medium-risk group.

These observations suggest that risk scores generated for individual patients by different periodontal risk assessment models are highly variable. When used in periodontal clinical decision-making, choice of the periodontal risk model could affect the risk assessment and may result in the misapplication of treatment for some patients. Long-term study on the validity and accuracy of current periodontal risk assessment models are needed to better achieve the goal of early identification of at-risk populations and formulation of proactive targeted interventions.

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Appendix I. McGuire's Tooth Prognosis Classification. Modified from McGuire, M. Prognosis versus actual outcome: a long-term survey of 100 treated periodontal patients under maintenance care. J Periodontol. 1991 Jan;62(1):51-8.

Prognosis Category	Category Criteria
Good	(one or more of the following) Adequate periodontal support and control of the etiological factors to assure the tooth would be relatively easy to maintain, assuming proper maintenance.
Fair	(one or more of the following) Attachment loss to the point that the tooth could not be considered to have a good prognosis and/or class I furcation involvement. The location and depth of the furcation would allow proper maintenance with good patient compliance.
Poor	(one or more of the following) Moderate attachment loss with class I and/or class II furcations. The location and depth of the furcations would allow proper maintenance, but with difficulty.
Questionable	(one or more of the following) Severe attachment loss resulting in a poor crown-to-root ratio. Poor root form. Class II furcations not easily accessible to to maintenance care or class III furcations. 2+ mobility or greater. Significant root proximity.
Hopeless	Inadequate attachment to maintain the tooth in health, comfort, and function. Extraction is suggested.
If there is a question as to which prognosis a tooth should be given, the operator should assign the better of the two prognoses.	

Appendix II. Factors to Consider When Assigning a Prognosis. From McGuire, M. Prognosis versus actual outcome: a long-term survey of 100 treated periodontal patients under maintenance care. J Periodontol. 1991 Jan;62(1):51-8.

Individual Tooth Prognosis	Overall Prognosis
Percentage of bone loss	Age
Probing depth	Medical status
Distribution and type of bone loss	Individual tooth prognosis
Presence and severity of furcations	Rate of progression
Mobility	Patient cooperation
Crown to root ratio	Economic considerations
Root form	Knowledge and ability of dentist
Pulpal involvement	Etiologic factors
Caries	Oral habits and compulsions
Tooth position and occlusal relationship	
Strategic value	
Therapist knowledge and skill	

Appendix III. Subject Data

Code	Sex/ Age	PRA Risk; Surface Area	PRC Risk; Disease Severity	Smoking	Diabetes; level of control
723869	M63	M; 22.9496	H 4/5, 58/100	never	no
127072	F67	M; 18.6195	H4/5, 52/100	Q <10cig/d, <10yrs	no
128362	F65	M; 11.6913	M3/5, 25/100	never	no

135495	M75	M; 12.1243	L2/5, 33/100	never	no
140547	F62	M; 25.1147	H4/5, 59/100	never	no
150754	F60	H; 52.3945	H4/5, 64/100	never	no
151476	M58	H; 66.2509	H4/5, 77/100	Q<10cig/d, >10yrs	no
155069	F67	H:59.3227	H4/5, 61/100	never	no
156499	F52	H:81.4063	H5/5, 100/100	never	yes; poor
157828	F75	H:51.9615	H4/5, 64/100	never	yes; fair
158629	F61	H:766432	H4/5; 82/100	never	yes; fair
160463	F82	L:13.8564	H4/5; 57/100	never	no
161405	M78	H:81.4063	H5/5; 99/100	never	yes; poor
163102	F77	M:45.8993	M3/5; 9/100	Q>10yrs	no
165345	F65	L:2.59807	M3/5; 26/100	never	no
166518	M59	L:6.0622	L2/5; 3/100	never	no
E456379	M46	H:44.1672	M3/5; 10/100	never	no
168987	F72	H: 58.0237	H4/5; 80/100	S<10cigs; >10yrs	no
E001447	M29	H:42.4352	H5/5; 58/100	never	no
E156955	F57	L:9.5263	H4/5; 18/100	S<10cigs; >10yrs	no

Code	#teeth/implants (28 total)	Missing teeth	BOP sites	#sites w/ PPD ≥ 5mm	%Alveolar Bone loss	Furcation	SubG Rest	Vertical Bone Lesion
723869	25	3	20	8	30	Y	N	Y
127072	27	1	32	3	35	Y	Y	Y

128362	23 /2	5	30	2	28	Y	Y	N
135495	28	0	0	27	44	Y	Y	N
140547	26	2	42	6	30	Y	Y	N
150754	25	3	109	15	45	Y	Y	N
151476	23	5	60	7	76	Y	Y	Y
155069	23	5	57	24	25	Y	Y	Y
156499	27	1	85	88	63	Y	N	Y
157828	24	4	24	15	37	Y	N	Y
158629	23	5	48	29	38	Y	Y	Y
160463	25	3	14	6	17	Y	Y	N
161405	27	1	103	25	82	Y	Y	Y
163102	17	11	3	7	40	Y	Y	N
165345	26	2	6	0	16	N	Y	N
166518	26/2	2	26	0	12	N	Y	N
E456379	26/1	1	83	16	11	N	N	N
168987	28	0	44	30	53	Y	Y	Y
E001447	28	0	45	18	19	N	N	N
E156955	24	4	2	1	24	y	y	n

Code	SubG calculus	H/O SRP	H/) Perio Surgery	Compliance	UR Probing Depth	UA Probing Depth	UL Probing Depth	LR Probing Depth	LA Probing Depth	LL Probing Depth
723869	N	Y	N	R	5-7mm	<5	5-7mm	5-7mm	<5	<5
127072	N	Y	N	R	<5	<5	>7	<5	<5	<5

128362	N	N	N	I	5-7mm	<5	<5	<5	<5	<5
135495	N	Y	N	R	5-7mm	<5	5-7mm	5-7mm	5-7mm	5-7mm
140547	Y	Y	N	I	5-7mm	<5	>7	5-7mm	<5	<5
150754	Y	Y	N	R	5-7mm	<5	5-7mm	5-7mm	<5	<5
151476	Y	Y	N	R	<5	<5	<5	5-7mm	<5	5-7mm
155069	Y	Y	N	R	5-7mm	<5	>7	5-7mm	<5	5-7mm
156499	Y	N	N	I	>7	>7	>7	>7	5-7mm	>7
157828	Y	Y	Y	R	>7	5-7mm	5-7mm	5-7mm	<5	<5
158629	Y	Y	Y	I	5-7mm	<5	>7	5-7mm	<5	5-7mm
160463	Y	Y	Y	R	5-7mm	<5	5-7mm	>7	<5	<5
161405	Y	Y	Y	I	>7	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm
163102	Y	Y	Y	R	5-7mm	<5	5-7mm	<5	<5	<5
165345	N	Y	N	I	<5	<5	<5	5-7mm	<5	5-7mm
166518	N	N	N	I	<5	<5	<5	<5	<5	<5
E456379	Y	Y	N	I	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
168987	Y	Y	N	I	5-7mm	5-7mm	>7	5-7mm	<5	5-7mm
E001447	Y	N	N	I	5-7mm	<5	5-7mm	>7	5-7mm	5-7mm
E156955	y	n	n	I	<5	<5	<5	5-7mm	<5	<5

Code	UR Alveolar	UA Alveolar	UL Alveolar	LR Alveolar	LA Alveolar	LL Alveolar

	Bone Loss	Bone Loss	Bone Loss	Bone Loss	Bone Loss	Bone Loss
723869	2-4mm	<2	>4	2-4mm	>4	2-4mm
127072	2-4mm	2-4mm	>4	<2	>4	<2
128362	2-4mm	<2	2-4mm	2-4mm	>4	<2
135495	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
140547	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
150754	2-4mm	>4	2-4mm	>4	>4	>4
151476	>4	2-4mm	2-4mm	>4	2-4mm	>4
155069	2-4mm	<2	>4	2-4mm	2-4mm	2-4mm
156499	>4	>4	>4	>4	>4	>4
157828	2-4mm	2-4mm	2-4mm	2-4mm	>4	2-4mm
158629	>4	2-4mm	2-4mm	2-4mm	>4	2-4mm
160463	2-4mm	<2	2-4mm	2-4mm	2-4mm	<2
161405	>4	>4	>4	2-4mm	>4	>4
163102	<2	2-4mm	<2	2-4mm	<2	<2
165345	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
166518	<2	<2	<2	<2	<2	<2
E456379	<2	2-4mm	<2	<2	<2	<2
168987	>4	<2	>4	2-4mm	2-4mm	2-4mm
E001447	2-4mm	<2	<2	2-4mm	2-4mm	<2
E156955	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm

Code	Sex/ Age	PRA Risk; Surface Area	PRC Risk; Disease Severity	Smoking	Diabetes; level of control

E258660	F49	L:19.9185	M3/5; 26/100	Q<10 yrs;>10cigsx10yrs,	no
E307274	M74	H:57.1576	H4/5; 82/100	Q>10yrs; >10cigsx15yrs	no
E302644	F62	M:18.1865	L2/5; 6/100	never	no
E417384	M65	H: 45.8993	H4/5; 64/100	S; 25cigsx50yrs	no
E419298	F55	M:18.1865	H4/5; 25/100	never	no
E428159	M30	M:12.1243	L2/5; 5/100	never	no
E429563	M55	H: 75.3442	H4/5; 59/100	never	yes; fair
E430362	F45	M: 28.1458	H4/5: 24/100	Q<10 yrs;>10cigsx30yrs,	no
E430379	F29	M: 25.1147	H4/5; 17/100	never	no
E430405	M57	L:6.9682	L2/5; 3/100	never	no
E430460	M68	M: 28.1458	H4/5; 25/100	Q>10yrs; 10 cigsx13 yrs	yes; poor
E430491	F51	H: 119.078	H5/5; 97/100	never	no
E430612	M59	M: 24.2487	H5/5; 72/100	never	no
E430638	F55	L: 4.3301	H4/5: 18/100	never	no
E430675	F38	H: 54.1265	H5/5; 51/100	Q,10yrs; 2cigx10yrs	no
E470567	F63	M: 12.1243	H4/5; 62/100	never	no
E477938	M59	M: 15.1554	H4/5; 64/100	never	no
E441692	F53	H: 96.9948	H5/5; 92/100	S; 7cigsx20yrs	no
E464118	M61	M: 22.9496	M3/5; 34/100	never	no
E461545	M57	H: 55.4256	H4/5; 82/100	never	yes; fair
629424	M56	H: 64.9519	H5/5; 100/100	never	no

E453514	F46	M: 22.5166	H4/5; 31/100	never	no

Code	#teeth/implants (28 total)	Missing teeth	BOP sites	#sites w/ PPD ≥ 5mm	%Alveolar Bone loss	Furcation	SubG Rest	Vertical Bone Lesion
E258660	26	2	30	4	14	n	y	N
E307274	27	1	156	32	59	y	y	Y
E302644	28	0	95	4	10	n	y	N
E417384	21	7	6	56	32	y	y	N
E419298	24	4	15	4	34	y	n	N
E428159	24	4	49	1	11	n	n	N
E429563	18	10	3	3	64	y	y	N
E430362	22	6	37	3	13	n	y	N
E430379	28	0	25	17	15	n	n	N
E430405	28	0	30	0	13	y	y	N
E430460	23	5	8	2	24	y	y	N
E430491	23	5	82	30	54	y	n	Y
E430612	22	6	3	6	39	y	n	N
E430638	28	0	8	1	21	n	y	N
E430675	24	4	28	9	42	n	y	Y
E470567	27	1	1	22	42	y	y	Y
E477938	25/3	3	4	44	28	n	y	N
E441692	22	6	48	10	58	y	y	Y
E464118	26	2	38	7	28	y	y	N
E461545	26	2	68	14	42	y	y	N

629424	24	4	88	45	62	y	y	Y
E453514	22	6	32	4	19	y	n	N

Code	SubG calculus	H/O SRP	H/) Perio Surgery	Compliance	UR Probing Depth	UA Probing Depth	UL Probing Depth	LR Probing Depth	LA Probing Depth	LL Probing Depth
E258660	n	n	n	I	5-7mm	<5	<5	<5	<5	5-7mm
E307274	y	n	n	I	>7	5-7mm	>7	5-7mm	5-7mm	5-7mm
E302644	n	n	n	I	5-7mm	<5	<5	5-7mm	<5	<5
E417384	y	y	n	r	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm	>7
E419298	y	y	n	r	5-7mm	<5	5-7mm	<5	<5	<5
E428159	n	n	n	r	<5	<5	5-7mm	<5	<5	<5
E429563	y	y	n	I	<5	<5	5-7mm	<5	<5	5-7mm
E430362	n	n	n	i	5-7mm	<5	<5	5-7mm	<5	<5
E430379	y	n	n	i	<5	<5	5-7mm	5-7mm	5-7mm	5-7mm
E430405	n	n	n	i	<5	<5	<5	<5	<5	<5
E430460	y	n	n	i	<5	<5	5-7mm	5-7mm	<5	<5
E430491	y	n	n	i	>7	5-7mm	5-7mm	5-7mm	5-7mm	>7
E430612	y	n	n	i	5-7mm	<5	>7	<5	<5	<5
E430638	y	n	n	i	<5	<5	<5	<5	<5	5-7mm
E430675	y	n	n	i	>7	<5	5-7mm	<5	<5	5-7mm
E470567	n	y	y	r	5-7mm	5-7mm	5-7mm	<5	5-7mm	5-7mm
E477938	y	n	n	i	>7	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm
E441692	y	y	n	i	5-7mm	<5	5-7mm	<5	<5	>7

E464118	y	y	n	r	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
E461545	n	y	n	i	>7	<5	5-7mm	5-7mm	5-7mm	5-7mm
629424	n	y	y	r	>7	>7	>7	5-7mm	5-7mm	>7
E453514	n	y	n	r	5-7mm	<5	5-7mm	5-7mm	<5	<5

Code	UR Alveolar Bone Loss	UA Alveolar Bone Loss	UL Alveolar Bone Loss	LR Alveolar Bone Loss	LA Alveolar Bone Loss	LL Alveolar Bone Loss
E258660	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E307274	>4	2-4mm	>4	2-4mm	2-4mm	2-4mm
E302644	<2	<2	<2	<2	<2	<2
E417384	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm
E419298	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
E428159	<2	<2	<2	<2	<2	<2
E429563	2-4mm	2-4mm	>4	2-4mm	>4	2-4mm
E430362	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
E430379	<2	<2	<2	<2	2-4mm	<2
E430405	<2	<2	<2	<2	<2	<2
E430460	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E430491	>4	2-4mm	>4	2-4mm	>4	2-4mm
E430612	>4	2-4mm	>4	2-4mm	2-4mm	2-4mm
E430638	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E430675	>4	<2	2-4mm	<2	<2	<2
E470567	2-4mm	2-4mm	>4	2-4mm	>4	2-4mm

E477938	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E441692	>4	>4	>4	2-4mm	>4	>4
E464118	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E461545	2-4mm	2-4mm	2-4mm	2-4mm	>4	2-4mm
629424	2-4mm	>4	2-4mm	>4	>4	2-4mm
E453514	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm

Code	Sex/ Age	PRA Risk; Surface Area	PRC Risk; Disease Severity	Smoking	Diabetes; level of control
E447902	M46	M: 12.5573	H5/5; 53/100	never	no
E472787	M42	H: 46.7653	H5/5; 88/100	S; 20cigsx15yrs	no
E474008	F48	H:77.9422	H5/5; 97/100	S; 5cigsx30yr	no
E433048	M71	M; 28.1458	L2/5; 31/100	never	no
550916	M69	H; 100.458	H4/5; 97/100	never	no
E444265	M71	L; 6.0622	M3/5; 46/100	never	no
E449509	F61	M; 58.4567	H5/5; 81/100	S; 1cigsx10 yrs	no
E448523	M38	M; 9.5263	M3/5; 8/100	never	no
E455137	F48	H; 50.2294	H5/5; 92/100	never	no
E445524	M26	L; 4.3301	H1/5; 2/100	never	no
E479540	M52	M; 9.5263	L2/5; 3/100	never	no
E434224	M57	M; 67.5499	H4/5; 80/100	Q>10yrs, 20cigsx10yrs	no
E468027	F36	H; 50.2294	H5/5; 43/100	S; 20cigsx12 yrs	no
792812	M58	M; 35.5070	H5/5; 70/100	never	no
E460012	F76	M; 29.4445	H4/5; 78/100	Q>10yrs,	no

				20cigsx20yrs	
671862	M67	M; 16.4544	H4/5; 59/100	never	no
E473737	M68	M; 13.8564	M3/5; 30/100	S; 2cigars/wk>10yrs	no
257720	F53	H; 33.7749	H4/5, 64/100	Q>10yrs, 2cigsx10yrs	no
E456377	F47	H; 42.4352	H4/5; 97/100	never	yes; good
E456692	F67	M; 27.2796	H4/5; 53/100	never	no
E451149	F34	M; 11.2583	H4/5; 19/100	never	no

Code	#teeth/implants (28 total)	Missing teeth	BOP sites	#sites w/ PPD ≥ 5mm	%Alveolar Bone loss	Furcation	SubG Rest	Vertical Bone Lesion
E447902	23/3	5	8	2	34	y	n	y
E472787	26	2	20	17	54	y	n	y
E474008	24	4	39	45	80	y	n	y
E433048	27	3	25	22	27	y	y	n
550916	17/4	11	46	34	56	y	y	y
E444265	28	0	24	1	26	y	y	n
E449509	23/1	5	27	27	41	y	n	y
E448523	28	0	48	2	16	n	n	n
E455137	27	1	70	19	54	y	y	y
E445524	28	0	9	0	10	n	n	n
E479540	28	0	73	0	0.7	n	n	n
E434224	22	4	28	13	43	y	y	y
E468027	27	1	89	2	23	y	n	y
792812	28	0	31	29	47	y	y	y

E460012	27	1	25	11	49	y	y	y
671862	27	1	12	19	38	y	y	y
E473737	26	2	6	34	19	y	y	n
257720	26	2	17	14	70	y	n	y
E456377	27	1	13	15	42	y	n	y
E456692	25/1	3	23	2	40	y	n	y
E451149	28	0	40	2	26	y	n	n

Code	SubG calculus	H/O SRP	H/) Perio Surgery	Compliance	UR Probing Depth	UA Probing Depth	UL Probing Depth	LR Probing Depth	LA Probing Depth	LL Probing Depth
E447902	n	y	y	r	<5	<5	<5	5-7mm	<5	5-7mm
E472787	n	y	y	r	5-7mm	<5	>7	>7	<5	>7
E474008	y	y	n	r	5-7mm	5-7mm	5-7mm	>7	5-7mm	>7
E433048	y	y	n	r	5-7mm	5-7mm	5-7mm	<5	<5	5-7mm
550916	n	y	n	i	5-7mm	5-7mm	>7	5-7mm	5-7mm	5-7mm
E444265	n	n	n	i	>7	<5	<5	<5	<5	<5
E449509	n	y	y	i	5-7mm	<5	5-7mm	5-7mm	<5	>7
E448523	y	y	n	r	<5	<5	<5	5-7mm	<5	5-7mm
E455137	y	y	n	i	<5	5-7mm	>7	5-7mm	<5	5-7mm
E445524	n	n	n	r	<5	<5	<5	<5	<5	<5
E479540	y	y	n	i	<5	<5	<5	<5	<5	<5
E434224	y	y	n	i	5-7mm	<5	5-7mm	5-7mm	<5	<5
E468027	y	y	n	r	<5	<5	5-7mm	<5	<5	<5
792812	y	y	n	r	>7	<5	>7	5-7mm	<5	5-7mm

E460012	n	y	y	r	<5	<5	5-7mm	<5	<5	5-7mm
671862	n	y	n	r	5-7mm	5-7mm	<5	5-7mm	<5	<5
E473737	n	y	n	r	5-7mm	5-7mm	5-7mm	5-7mm	<5	5-7mm
257720	n	y	n	r	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm
E456377	n	y	n	i	5-7mm	5-7mm	5-7mm	5-7mm	<5	5-7mm
E456692	n	y	y	r	<5	<5	5-7mm	<5	5-7mm	<5
E451149	n	y	n	i	<5	<5	<5	5-7mm	<5	<5

Code	UR Alveolar Bone Loss	UA Alveolar Bone Loss	UL Alveolar Bone Loss	LR Alveolar Bone Loss	LA Alveolar Bone Loss	LL Alveolar Bone Loss
E447902	2-4mm	<2	2-4mm	>4	2-4mm	2-4mm
E472787	2-4mm	<2	>4	>4	<2	>4
E474008	2-4mm	>4	2-4mm	>4	>4	>4
E433048	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
550916	2-4mm	>4	2-4mm	>4	>4	2-4mm
E444265	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E449509	>4	<2	2-4mm	2-4mm	>4	>4
E448523	2-4mm	<2	<2	<2	<2	<2
E455137	>4	>4	>4	>4	2-4mm	2-4mm
E445524	<2	<2	<2	<2	<2	<2
E479540	<2	<2	<2	<2	<2	<2
E434224	2-4mm	>4	>4	>4	2-4mm	2-4mm
E468027	2-4mm	<2	>4	2-4mm	<2	<2

792812	>4	<2	2-4mm	<2	<2	<2
E460012	>4	2-4mm	>4	>4	2-4mm	>4
671862	>4	<2	2-4mm	2-4mm	>4	2-4mm
E473737	2-4mm	<2	2-4mm	2-4mm	<2	<2
257720	2-4mm	<2	2-4mm	2-4mm	>4	2-4mm
E456377	>4	>4	>4	>4	>4	2-4mm
E456692	2-4mm	2-4mm	2-4mm	2-4mm	>4	2-4mm
E451149	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm

Code	Sex/ Age	PRA Risk; Surface Area	PRC Risk; Disease Severity	Smoking	Diabetes; level of control
720380	F61	H; 20.7846	L2/5; 33/100	never	yes; fair
E437520	M30	H; 70.1480	m3/5; 10/100	S;12cigs/dx>10yrs	no
763412	M83	M; 67.5499	H4/5; 53/100	never	no
E436324	F72	M; 19.0525	M3/5; 57/100	never	no
797966	F69	M16.8874	M3/5; 22/100	never	no
741197	M58	H; 72.7461	H5/5; 92/100	never	yes, poor
738568	M66	H; 61.4878	H4/5; 35/100	never	no
792120	M38	M; 33.7749	H5/5; 76/100	S; 2cigs/d x 18 yrs	no
795373	M33	M; 44.1672	H5/5; 15/100	S; 10cigs/d x 11yrs	no
E435723	M62	H; 81.4063	H5/5; 100/100	S; 20cigsday x 30 yrs	no
638013	M47	L; 3.4641	L1/5; 4/100	never	no

790587	F44	H; 46.7653	H4/5; 26/100	never	yes, good
660237	M58	M; 9.5263	H4/5; 16/100	never	no
726686	M54	M; 51.0954	H4/5; 82/100	never	no
745827	M44	M; 25.5477	H5/5; 13/100	S;10cigs/d x >10yrs	no
235870	M85	M; 29.0118	L2/5; 31/100	never	no
793392	F42	H; 74.9111	M3/5; 34/100	never	no
785197	M47	L; 8.6603	H4/5; 11/100	never	no
753589	M52	M; 35.5070	H5/5; 90/100	never	no
786719	M61	M; 10.3923	H4/5; 16/100	never	yes; poor

Code	#teeth/implants (28 total)	Missing teeth	BOP sites	#sites w/ PPD ≥ 5mm	%Alveolar Bone loss	Furcation	SubG Rest	Vertical Bone Lesion
720380	28	0	3	34	17	y	n	n
E437520	28	0	71	35	7	y	n	n
763412	20/5	8	32	19	47	n	y	y
E436324	28	0	19	8	32	y	n	n
797966	27/1	1	16	7	28	y	n	n
741197	26	2	62	21	51	y	n	y
738568	17	13	0	7	49	y	n	y
792120	28	0	24	27	25	y	y	n
795373	24	4	27	6	15	n	n	n
E435723	26	2	123	82	42	y	y	y
638013	25/1	3	7	0	10	n	n	n
790587	26/2	2	42	17	13	y	n	n

660237	26/2	2	0	16	11	y	n	n
726686	23	5	76	7	50	y	n	y
745827	26	2	16	5	21	n	n	n
235870	23	5	10	11	27	y	y	y
793392	21	7	76	10	22	n	n	n
785197	28	0	14	4	30	y	n	n
753589	28	0	38	20	40	y	n	y
786719	25	3	0	1	15	y	y	n

Code	SubG calculus	H/O SRP	H/) Perio Surgery	Compliance	UR Probing Depth	UA Probing Depth	UL Probing Depth	LR Probing Depth	LA Probing Depth	LL Probing Depth
720380	n	y	y	r	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
E437520	n	y	n	i	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
763412	n	y	y	r	>7	<5	5-7mm	5-7mm	<5	5-7mm
E436324	n	y	n	i	<5	<5	5-7mm	>7	<5	5-7mm
797966	n	y	n	i	5-7mm	5-7mm	<5	<5	<5	<5
741197	y	y	y	i	>7	5-7mm	5-7mm	5-7mm	<5	5-7mm
738568	n	y	y	r	<5	5-7mm	<5	5-7mm	<5	<5
792120	n	y	y	i	>7	<5	5-7mm	5-7mm	5-7mm	>7
795373	n	y	y	i	5-7mm	<5	5-7mm	<5	<5	5-7mm
E435723	n	y	n	i	>7	>7	>7	>7	>7	>7
638013	n	n	n	r	<5	<5	<5	<5	<5	<5
790587	y	y	y	r	<5	<5	5-7mm	5-7mm	<5	5-7mm

660237	n	y	y	r	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
726686	n	y	n	r	5-7mm	<5	<5	<5	5-7mm	5-7mm
745827	n	y	y	r	5-7mm	<5	<5	<5	<5	5-7mm
235870	n	y	n	r	5-7mm	<5	5-7mm	5-7mm	<5	<5
793392	n	y	n	r	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm	5-7mm
785197	n	y	y	r	<5	<5	<5	5-7mm	<5	<5
753589	n	y	y	r	5-7mm	5-7mm	>7	<5	5-7mm	5-7mm
786719	n	y	y	i	<5	<5	<5	5-7mm	<5	<5

Code	UR Alveolar Bone Loss	UA Alveolar Bone Loss	UL Alveolar Bone Loss	LR Alveolar Bone Loss	LA Alveolar Bone Loss	LL Alveolar Bone Loss
720380	2-4mm	<2	2-4mm	2-4mm	2-4mm	2-4mm
E437520	<2	<2	<2	<2	<2	<2
763412	>4	<2	2-4mm	<2	2-4mm	<2
E436324	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
797966	2-4mm	2-4mm	<2	2-4mm	<2	<2
741197	>4	<2	2-4mm	>4	>4	>4
738568	>4	2-4mm	>4	2-4mm	>4	>4
792120	2-4mm	<2	2-4mm	<2	<2	2-4mm
795373	2-4mm	<2	<2	<2	<2	<2
E435723	>4	>4	>4	2-4mm	>4	2-4mm
638013	<2	<2	<2	<2	<2	2-4mm
790587	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm

660237	2-4mm	<2	<2	<2	<2	<2
726686	2-4mm	>4	>4	>4	>4	>4
745827	<2	<2	<2	<2	<2	2-4mm
235870	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm
793392	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
785197	<2	<2	<2	2-4mm	<2	<2
753589	>4	<2	>4	2-4mm	>4	2-4mm
786719	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm

Code	Sex/ Age	PRA Risk; Surface Area	PRC Risk; Disease Severity	Smoking	Diabetes; level of control
643582	F65	M; 56.2916	H4/5; 16/100	never	no
242000	M51	M; 22.5166	M3/5; 9/100	never	no
796116	M50	L; 8.6603	H5/5; 25/100	Q; 20cigs/dx15yrs,<10yrs	no
791163	M30	M; 12.1243 (6)	H5/5; 22/100	never	no
778484	M81	L; 5.6292	M3/5; 24/100	never	no
674722	F72	H; 103.057	M3/5; 62/100	S; 2cigs/d x 8 yrs	no
E438630	M66	M; 25.1147 (6)	H5/5; 62/100	never	no
790587	F44	H; 51.0954	H4/5; 33/100	never	yes; good
E429096	F49	M; 8.6603	L2/5; 8/100	never	no

773022	M45	M; 20.7846	L2/5; 8/100	never	no
157828	F75	H; 53.6935	H4/5; 68/100	never	yes; good
E463890	M47	H; 66.6839	H5/5; 92/100	never	no
E432557	F49	M; 46.7653	H5/5; 46/100	never	no
E442581	F35	L; 4.7631	L2/5; 10/100	never	no
E440980	F65	M; 22.0836	H4/5; 64/100	never	no
E441048	F64	H; 25.5477	H4/5; 34/100	never	yes; good
E439942	M52	M; 24.2487	H4/5; 22/100	never	no

Code	#teeth/implants (28 total)	Missing teeth	BOP sites	#sites w/ PPD ≥ 5mm	%Alveolar Bone loss	Furcation	SubG Rest	Vertical Bone Lesion
643582	20/4	8	39	8	20	y	n	n
242000	23	5	6	25	7	y	n	n
796116	27	1	9	1	37	y	n	y
791163	28	0	2	8	26	y	n	y
778484	26	2	12	3	28	n	y	n
674722	18	10	37	11	50	y	y	y
E438630	26	2	23	24	40	y	y	y
790587	26/2	2	35	13	32	y	n	y
E429096	27	1	4	9	5	n	n	n

773022	24	4	18	6	20	n	n	n
157828	24	4	24	14	38	y	n	n
E463890	24	4	86	32	60	y	n	y
E432557	20	8	15	6	40	y	n	y
E442581	25	3	0	0	15	n	n	n
E440980	28	0	12	42	33	y	n	n
E441048	26	2	7	10	30	y	n	n
E439942	17	11	8	4	25	n	n	n

Code	SubG calculus	H/O SRP	H/) Perio Surgery	Compliance	UR Probing Depth	UA Probing Depth	UL Probing Depth	LR Probing Depth	LA Probing Depth	LL Probing Depth
643582	n	y	y	r	<5	5-7mm	<5	<5	<5	5-7mm
242000	n	y	n	r	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
796116	n	y	y	r	<5	<5	<5	5-7mm	<5	<5
791163	n	y	y	r	5-7mm	<5	<5	5-7mm	<5	5-7mm
778484	n	y	y	r	5-7mm	<5	<5	<5	<5	5-7mm
674722	n	y	n	r	>7	5-7mm	<5	<5	5-7mm	<5
E438630	n	y	y	i	<5	>7	5-7mm	5-7mm	<5	5-7mm
790587	n	y	y	i	5-7mm	<5	5-7mm	5-7mm	<5	5-7mm
E429096	n	y	n	r	5-7mm	<5	5-7mm	5-7mm	<5	<5
773022	n	y	n	i	5-7mm	<5	5-7mm	<5	<5	<5
157828	n	y	n	r	>7	5-7mm	5-7mm	<5	<5	<5
E463890	y	y	y	i	5-7mm	5-7mm	>7	>7	<5	>7

E432557	n	y	y	r	<5	<5	<5	>7	<5	<5
E442581	n	n	n	r	<5	<5	<5	<5	<5	<5
E440980	y	y	y	i	5-7mm	<5	5-7mm	5-7mm	5-7mm	5-7mm
E441048	n	y	y	r	5-7mm	<5	<5	5-7mm	<5	5-7mm
E439942	n	y	y	r	5-7mm	<5	<5	<5	<5	5-7mm

Code	UR Alveolar Bone Loss	UA Alveolar Bone Loss	UL Alveolar Bone Loss	LR Alveolar Bone Loss	LA Alveolar Bone Loss	LL Alveolar Bone Loss
643582	2-4mm	2-4mm	2-4mm	<2	<2	<2
242000	<2	<2	<2	<2	<2	<2
796116	>4	<2	2-4mm	2-4mm	2-4mm	2-4mm
791163	2-4mm	<2	<2	<2	<2	2-4mm
778484	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm
674722	2-4mm	2-4mm	2-4mm	>4	2-4mm	2-4mm
E438630	2-4mm	>4	2-4mm	2-4mm	>4	2-4mm
790587	2-4mm	2-4mm	2-4mm	2-4mm	<2	2-4mm
E429096	<2	<2	<2	<2	<2	<2
773022	<2	<2	<2	<2	<2	2-4mm
157828	>4	2-4mm	>4	2-4mm	2-4mm	2-4mm
E463890	2-4mm	2-4mm	>4	>4	2-4mm	>4
E432557	2-4mm	2-4mm	2-4mm	>4	2-4mm	2-4mm
E442581	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm	2-4mm
E440980	2-4mm	2-4mm	2-4mm	2-4mm	>4	2-4mm

E441048	2-4mm	2-4mm	2-4mm	2-4mm	>4	2-4mm
E439942	2-4mm	<2	2-4mm	2-4mm	<2	2-4mm

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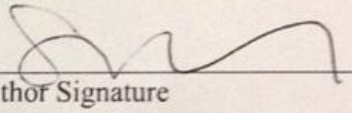

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