



Comparison of two different periodontal risk assessment methods with regard to their agreement: Periodontal risk assessment versus periodontal risk calculator

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Abstract

Aim: To evaluate the level of agreement between the periodontal risk assessment (PRA) and the periodontal risk calculator (PRC).

Materials and methods: Periodontal risk was retrospectively assessed among 50 patients using PRA and PRC. Both methods were modified. PRA by assessing probing pocket depths and bleeding on probing at four (PRA4) and six (PRA6) sites per tooth, PRC by permanently marking or unmarking the dichotomously selectable factors “irregular recall,” “oral hygiene in need of improvement” and “completed scaling and root planing” for PRC. Agreement between PRA and PRCred (summarized risk categories) was determined using weighted kappa.

Results: Fifty patients enrolled in periodontal maintenance (48% female, age: 63.8 ± 11.2 years) participated. PRA4 and PRA6 matched in 32 (64%) patients (κ -coefficient = 0.48, $p < .001$). There was 100% agreement between both PRC versions. There was minimal agreement of PRA6 and PRCred (66%, 28% one different category, 6% two different categories; κ -coefficient = 0.34; $p = .001$). PRA4 and PRCred did not match (60% agreement, 34% one different category, 6% two different categories; κ -coefficient = 0.23; $p = .13$). For the SPT diagnosis of severe periodontitis, PRA6 and PRCred agreed weakly (κ -coefficient = 0.44; $p = .004$).

Conclusion: PRA and PRC showed a minimal agreement. Specific disease severity may result in improved agreement.

KEYWORDS

periodontal disease progression, periodontal risk assessment, periodontal risk calculator, risk factors

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1 | INTRODUCTION

Various periodontal risk assessment methods are available for determination of patients' individual risk (Chandra, 2007; Dhulipalla et al., 2015; Lang & Tonetti, 2003; Lindskog et al., 2010a, 2010b; Page, Krall, Martin, Mancl, & Garcia, 2002; Trombelli et al., 2017). However, agreement of the two most commonly used methods (periodontal risk assessment: PRA; periodontal risk calculator: PRC) has hardly been described so far (Sai Sujai, Triveni, Barath, & Harikishan, 2015). Due to previous disease experience, all periodontitis patients have an individual risk of further disease progression or even relapse after completion of active periodontal therapy (APT) (Ferraiolo, 2016). This probability of something happening (e.g., suffering from disease/-progression) is known as risk. Factors that contribute to risk are so-called risk factors. According to current understanding, factors that increase the likelihood of progression in previously diseased patients are called "prognostic factors." The present study has not further distinguished risk from prognostic factors based on the use of terms by the authors of PRA and PRC (Lang & Tonetti, 2003; Page et al., 2002).

Defining progression is difficult. Some use attachment loss of ≥ 1.3 mm (Harks et al., 2015), some use ≥ 2 mm (Claffey, Nylund, Kiger, Garrett, & Egelberg, 1990; Lang, Joss, Orsanic, Gusberti, & Siegrist, 1986; Tonetti, Claffey, & European Workshop in Periodontology Group C, 2005) and others use ≥ 3 mm (Kaldahl, Kalkwarf, Patil, Molvar, & Dyer, 1996; Socransky, Haffajee, Goodson, & Lindhe, 1984) as a threshold for progression. Applicability of different thresholds is a matter of reliability of measurements as well as of sensitivity and specificity. Moreover, the current classification for periodontal diseases defines three different grades (A, B, C), which distinguish slow (A), moderate (B) or rapid (C) disease progression (Tonetti, Greenwell, & Kornman, 2018). A robust measure of the result of periodontal progression is tooth loss. Thus, many publications assess risk factors for tooth loss as result of progressing attachment loss (Baumer et al., 2011; Dannewitz et al., 2016; Eickholz, Kaltschmitt, Berbig, Reitmeir, & Pretzl, 2008; Graetz, Plaumann, et al., 2017; Graetz, Salzer, et al., 2017; Kocher et al., 2005; Muller, Eickholz, Reitmeir, & Eger, 2013; Pretzl, Kaltschmitt, Kim, Reitmeir, & Eickholz, 2008; Pretzl, El Sayed, Weber, Eickholz, & Baumer, 2018). These factors may be employed to predict a patient's individual probability to suffer from disease progression (so-called risk assessment). Two often-cited multifactorial risk assessment systems were developed for objectivity and quantification of risk factors by Page et al. (PRC, Page et al., 2002) and Lang and Tonetti (PRA, Lang & Tonetti, 2003). Original PRC is based on mathematical algorithms that assign relative weights to 11 factors and enable stratification of the results into five categories (1 = very low risk to 5 = very high risk) (Page et al., 2002). PRA, on the other hand, uses six factors that are related to progression of periodontitis. The result of the PRA is the individual risk stratification into three categories (low, moderate, high risk) (Lang & Tonetti, 2003).

Knowledge about the risk of disease progression practically may be used for assignment of SPT intervals or to control modifiable risk factors (Ramseier & Lang, 1999).

Clinical Relevance

Scientific rationale for the study: Considering the multifactorial character of periodontal disease the comparability of two periodontal risk assessment methods (periodontal risk assessment and periodontal risk calculator) was evaluated.

Principal findings: The assessment of the individual risk for the progression of periodontitis using two different risk assessment methods showed only a minimal agreement.

Practical implications: Using a tool for periodontal risk assessment seems plausible for the organization of a risk factor-based recall system during supportive periodontal therapy. However, the evaluated methods for the calculation of the patient's individual risk may provide inconsistent allocation to different risk categories.

The aim of this study was to compare both tools for PRA in the originally described and in a modified version among a SPT patient cohort in order to evaluate the accordance of the resulting risk assignment. This is based on the hypothesis that the results of both risk analysis methods do not significantly differ from each other with regard to the calculated risk categories and SPT interval assignments.

2 | MATERIALS AND METHODS

2.1 | Patients

In the present cohort study, data of patients were analysed who had undergone periodontal therapy (subgingival instrumentation according to the full-mouth disinfection concept, in combination with the adjunctive systemic antibiotics if *Aggregatibacter actinomycetemcomitans* had been detected subgingivally and after re-evaluation periodontal surgery if necessary) at the Department of Periodontology of the Johann Wolfgang Goethe-University Frankfurt/Main beginning in April 2005 (Eickholz et al., 2013). All patients were in SPT for different periods of time at re-examination and met the following inclusion criteria:

1. age ≥ 18 years at start of the therapy,
2. complete periodontal status at time of re-examination with pocket probing depths (PPD), clinical vertical attachment level (CAL-V) and bleeding on probing (BOP) at six sites per tooth,
3. evaluable radiographs (set of periapical or panoramic radiographs) that were ≤ 1 year old at the time of re-examination,
4. if patients were diabetics at the follow-up (SPT) examination, a recent HbA1c value not older than 3 months available from their medical history

A sample of cells from the cheek mucosa was obtained using a foam swab wiped over it for 20s. The sample was then sent for

laboratory analysis to detect the presence of the interleukin-1 β polymorphism (GenoType[®] IL-1; Hain Lifescience GmbH, Nehren, Germany).

The study protocol was approved by the Institutional Review Board for Human Studies of the Medical Faculty of the Johann Wolfgang Goethe-University (approval number 206/17). The study was registered in the German Register of Clinical Trials (DRKS, registration number: DRKS00017070).

Patients were diagnosed according to the 1999 classification of periodontal diseases valid at the time of the respective re-examination (SPT) (Armitage, 1999). Using periodontal charts documented at the respective SPT visit analysed for this study, all patients were assigned to stages according to the 2018 classification based on inter-proximal CAL-V, teeth missing due to periodontal reasons and complexity (Tonetti et al., 2018). A localized stage 3 periodontitis was classified as a moderate SPT diagnosis, and a generalized stage 3 or stage 4 periodontitis and a molar-incisor pattern with CAL-V \geq 5 mm were categorized as a severe baseline diagnosis. All patient-specific and tooth-specific parameters listed henceforth were taken from the medical history at re-examination or from the patient charts for transfer to the PRA or PRC. For assessment of radiographic parameters, the images were digitized (Microtek ScanMaker i800plus;

Microtek, Hsinchu, Taiwan) and evaluated using a computer program validated for distance measurements (SIDEXIS next-generation 1.51; Sirona, Bensheim, Germany). Bone loss was measured as the distance from the cemento-enamel-junction (CEJ) to the most apical extension of the bone defect. When the tooth was restored, the restoration margin was used as reference. In multi-rooted teeth, only the root with the apparently largest bone loss was measured (S.A.).

2.2 | PRA

PRA was based on the data collected for the following six parameters and calculated using a tabular form (Figure 1): (a) percentage of sites with BOP (BOP was assessed about 30 s after the collection of the probing parameters at six sites per tooth), (bb) number of residual pockets \geq 5 mm, (c) number of lost teeth except third molars (28 teeth) irrespective of their replacement (Lang & Tonetti, 2003), (d) loss of periodontal support in relation to the patient's age [bone loss-age index calculated as quotient of relative bone loss at the posterior tooth exhibiting most severe destruction estimated in percent of the root length by the patient's actual age (Lang & Tonetti, 2003)], (e) cigarette consumption

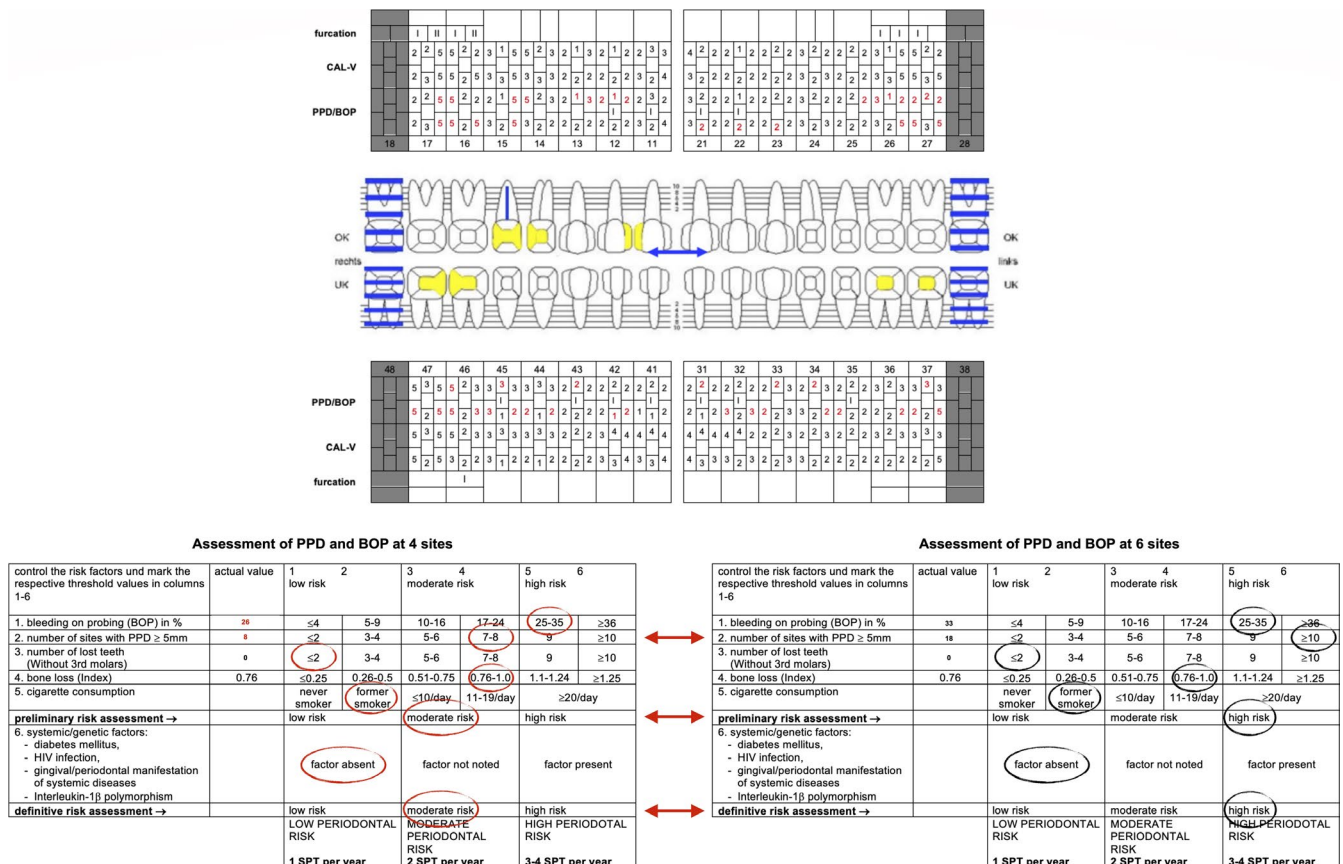


FIGURE 1 Periodontal risk assessment modified by Ramseier and Lang (1999) for an exemplary patient. The assessment of PPD and BOP at 4 (red) or 6 (black) sites per tooth changes the assignment to the respective risk category. In this case, a lower number of PPD \geq 5 mm was found for assessment of 4 instead of 6 sites per tooth. This leads to an assignment of a moderate risk category instead of the high category

[self-reported; a patient was considered non-smoker if she/he had never smoked and former smoker if she/he had stopped smoking five or more years ago; all others were considered active smokers (Lang & Tonetti, 2003)], (f) systemic/genetic factors [diabetes mellitus, HIV infection, interleukin-1 β polymorphism (patients were considered as IL-1 β -positive if the second allele for IL-A and IL-B was detected)].

Finally, a classification of low, moderate or high risk was assigned. If two factors were high risk, the patient was categorized as high risk. If two factors were of medium risk and only one additional factor was of high risk, the patient was categorized as moderate risk (Figure 1).

Percentage of residual pockets and BOP were assessed for six sites per tooth (mesiobuccal, buccal, distobuccal, distooral, oral, mesiooral) (PRA6) (standard measurements at the Dept. of Periodontology) and only four sites (mesiobuccal, buccal, distobuccal, oral) per tooth (PRA4), which has not been described in the original publication (Lang & Tonetti, 2003). To investigate this for both the originally described (4 sites per tooth) and the current standard (6 sites per tooth), both variants of the PRA were examined. The risk analysis was then repeated.

2.3 | PRC

For PRC risk assessment, the following factors were entered in a commercially accessible online platform (<http://www.previser.com>; Previser Corp., Concord, NH, USA): (a) gender; (b) age; (c) cigarette consumption (for active/former smokers according to the general medical history, the amount of nicotine consumption was given as <10, 10–19, or \geq 20 cigarettes/day, the duration of nicotine consumption was given as <10 or \geq 10 years); (d) oral hygiene in need of improvement (yes/no); (e) irregular recall interval (yes/no); (f) scaling and root planing (SRP) completed (yes/no); (g) periodontal surgery performed during APT or SPT (yes/no); (h) presence of furcation involvement (FI) (yes/no); (i) presence of subgingival restoration margins [yes, if an inter-proximal restoration margin (RM) was visible in the two-dimensional X-ray image and the corresponding inter-proximal CAL-V was at least at one site < PPD, assuming that the RM was equated in the measurements of the CEJ; otherwise, no]; (j) clinically/radiographically visible calculus (yes/no); (k) deepest PPD per sextant in categories (<5 mm, 5–7 mm, and >7 mm per sextant measured at six sites per tooth or edentulous sextant); (l) BOP per sextant (yes/no); and (m) radiological bone loss in categories (in each sextant, the site with the most severe bone loss was detected and categorized as <2 mm, 2–4 mm, or >4 mm). In addition, the distance between the CEJ/RM and the adjacent proximal bone level (=bone defect) and the distance CEJ/RM to the root tip (=root length) were measured and documented in mm. In the case of multi-rooted teeth, the root with the apparently largest bone loss was measured.

Subsequently, the digital tool calculated the so-called “Gum Disease Risk Score” comprising five categories (1 = very low risk,

2 = low risk, 3 = moderate risk, 4 = high risk and 5 = very high risk) using a not further defined algorithm was applied. The PRC was modified in such a way that the three dichotomous criteria “oral hygiene in need of improvement,” “irregular recall interval” and “SRP completed,” which were unclearly described by the provider and difficult to objectify, were consistently marked (PRCyes) or unmarked (PRCno) in all cases. In order to be able to show a difference, either all parameters were marked or unmarked.

2.4 | Statistics

According to other studies with similar objectives, a sample size of 50 patients was defined as appropriate (Dhulipalla et al., 2015; Sai Sujai et al., 2015).

A post hoc sample size calculation revealed, for a Cohen's weighted kappa of 0.7 with a test power of 80% and a type 1 error of $\alpha < .05$, a minimal sample size of 49 patients was ideal. However, this post hoc sample size calculation cannot be related to a reference since, to the best of our knowledge, no study so far has tested the agreement of both methods on the basis of Cohen's weighted kappa.

The patient was considered as statistical unit. The main outcome parameter was the agreement between both risk assessment methods for the modified and unmodified variant, which was considered the better the higher the kappa score was. To be able to relate a SPT interval to the PRC categories and to directly compare the two risk classifications, the five categories of the PRC were summarized into three categories (Sai Sujai et al., 2015): the categories “very low” and “low risk” as well as the categories “moderate” and “high risk” were each merged into one category “low” or “moderate risk” (reduced PRC = PRCred). The modifications of the PRA and PRC resulted in four different risk analyses per patient. The risk analyses were compared with each other using Cohen's weighted kappa according to the classification of inter-categorical agreement (κ -coefficient 0–0.20 = none agreement, 0.21–0.39 = minimal agreement, 0.40–0.59 = weak agreement, 0.60–0.79 = moderate agreement, 0.80–0.90 = strong agreement and > 0.90 = almost perfect) (McHugh, 2012).

Descriptive data were presented with respect to the scale level and distribution of the data. Data were checked for normal distribution using the Kolmogorov–Smirnov test. A type 1 error below 5% was accepted for statistical significance. The statistical analysis was carried out using a statistics program (IBM® SPSS® Statistics version 22 software package: IBM Corp., Armonk, NY, USA).

3 | RESULTS

3.1 | Patients

In this retrospective cohort study, the data of 50 SPT patients (24 females, average age: 63.8 \pm 11.2 years) assessed on average 8.18 \pm 2.28 years (range: 6–11 years) after completion of APT were

analysed for their individual periodontal risk at the time of SPT visit using PRA and PRC. Detailed demographic and patient-related data are summarized in Table 1.

3.2 | Clinical parameters

The PRA works by converting the number of sites with PPD \geq 5 mm into different categories. The assessment of PPD at four or six sites per tooth failed to show any total agreement (Table 2). Thirty-one out of 50 patients had more sites with PPD \geq 5 mm in the six-point measurement scheme (PRA6) and the risk category changed in 19 patients due to this difference. Fourteen patients (28%) showed a high risk according to PRA6. Following PRA4, only one patient (2%) was at high risk.

A total of 186 sextants (62%) had a value of $<$ 5 mm as the lowest PPD of the sextant, while 88 sextants (29.3%) showed results of between 5-7 mm and nine (3%) showed results of $>$ 7 mm.

The categorical distribution of the BOP for PRA4 and PRA6 is shown in Table 3 (suppl.). Nineteen out of 50 patients showed a higher BOP in case of a six-point measurement. Similar to the survey of PPD \geq 5 mm, 14 patients (28%) were at high risk for PRA6 as compared with patients (4%) at high risk for PRA4.

A total of 1,161 teeth, of which 378 were multi-rooted teeth (first upper pre-molars and all molars), were present at the time of re-examination. Of these multi-rooted teeth, 140 (37%) exhibited class I FI, 31 teeth (8.2%) class II, and 22 teeth (5.8%) had class III. A total of 185 teeth (49%) showed no FI (Hamp, Nyman, & Lindhe, 1975).

3.3 | Radiographic parameters

Twenty-seven patients (54%) had at least one vertical bone defect \geq 3 mm (Cortellini, Pini Prato, & Tonetti, 1993) at the time of follow-up. Subgingival calculus was visible on the radiographs in two patients (4%). The teeth were examined for the presence of an inter-proximal restoration: 264 teeth had a one- or two-sided inter-proximal restoration and 339 teeth had a crown. Considering inter-proximal sites with CAL-V $<$ PPD, a total number of 30 patients were classified as having subgingival RM.

3.4 | PRA

Figure 2 outlines the relative frequency of the evaluated risk factors for PRA4 and PRA6 separately.

Considering only four sites for measurement of PPD and BOP led to an increase of 30% points in the low-risk category (58% vs. 88% for PPD, 22% vs. 52% for BOP). In most cases, the risk score changed only by one category, but, in nine patients classified with high risk in the PPD category for PRA6, the risk score instead evolved to a low risk for PRA4 (Figure 2). For PRA6, 19 patients (38%) were assigned

TABLE 1 Demographic data and patient-related parameters

Parameter	n (%)
Gender	
Male	26 (52)
Female	24 (48)
Age at re-examination	63.8 \pm 11.2
Time in SPT	
Months	104.88 \pm 26.89
Years	8.2 \pm 2.25
Smoking habits	
Non-smoker	35 (70)
Former smoker	6 (12)
Smoker	9 (18)
SPT diagnosis	
Moderate periodontitis (Loc. stage III)	14 (27.5)
Severe periodontitis (Gen. stage III/stage IV/MIP)	36 (72.5) 20/15/1
Interleukin-1 polymorphism	
Positive	15 (30)
Negative	35 (70)
Diabetes	1 ^a (2)
Surgery during APT/SPT necessary (open flap debridement, regenerative or resective therapy)	28 (56)

Abbreviations: APT, active periodontal therapy; MIP, molar-incisor pattern; SPT, supportive periodontal therapy.

^aHbA1c: 6.5%.

to high risk, 29 (58%) to moderate risk, and two (4%) to low risk. With regard to PRA4, the percentage of patients demonstrating a high or moderate risk for BOP and the number of residual PPDs decreased. Overall, the addition of two sites to the measurement of BOP and PPD \geq 5 mm resulted in a 16% reduction of patients in the overall low risk and a 6% reduction in the moderate risk categories, respectively (Figure 2).

Subsequently, the agreement between PRA4 and PRA6 was tested. In 32 patients (64%), both methods revealed identical risk scores, while, in 18 patients (36%), the assessment by PRA4 resulted in a lower risk score as compared to PRA6 (Table 4). The agreement between the two models was weak, with a κ -coefficient of 0.48 (McHugh, 2012).

3.5 | PRC

Calculation of the individual risk using the "PRCyes" approach resulted in the following risk categories: 12 patients (24%) with very high risk, 23 (46%) with high risk, eight (16%) with moderate risk and seven (14%) with low risk. None of the patients were classified in the very low-risk category. If using "PRCno," there was no

TABLE 2 Comparison for periodontal risk assessment categories of number of sites with PPD \geq 5 mm for the assessment at 4 or 6 sites per tooth

			Number of PPD \geq 5 mm 6 sites per tooth						Overall (%) 4 sites per tooth
			Low risk		Moderate risk		High risk		
			≤ 2	3–4	5–6	7–8	9	≥ 10	
Number of PPD \geq 5 mm 4 sites per tooth	Low risk	≤ 2	16	11	1	3	0	0	31 (62)
		3–4	0	2	0	2	4	5	13 (26)
	Moderate risk	5–6	0	0	0	1	0	2	3 (6)
		7–8	0	0	0	0	0	2	2 (4)
	High risk	9	0	0	0	0	0	0	0 (0)
		≥ 10	0	0	0	0	0	1	1 (2)
Overall (%) 6 sites per tooth			16 (32)	13 (26)	1 (2)	6 (12)	4 (8)	10 (20)	50 (100)

Note: Agreements in risk categories are highlighted in grey.

difference among the results as compared with the activation of the three parameters (100% agreement). For comparison with the PRA, the original five categories of the PRC were summarized into three categories as previously stated [PRCred, (low risk: $n = 7$, moderate risk: $n = 31$, high risk: $n = 12$); Table 5]. Due to the complete match of the risk scores obtained by both approaches, results for the PRCred were not further differentiated for the comparison with the PRA.

3.6 | Comparison PRCred and PRA

Assessment of the periodontal risk by PRA and PRCred demonstrated heterogeneous results and, in some cases, marked differences in the assignment of the individual risk category. In 33 patients (66%), risk scores of PRA6 and PRCred agreed completely. In 10 patients (20%), the PRCred scores differed by one category, while, in three patients (6%), the PRC scores ranged two categories lower than the PRA6 risk scores. In four patients (8%), the PRA6 was one risk category lower than PRCred (Figure 3a). The agreement between PRA6 and PRCred was minimal (κ -coefficient = 0.34; $p = .001$) (McHugh, 2012). When comparing the agreement depending on the reclassified SPT diagnosis, a weak level of agreement was observed between PRA6 and PRCred for severe periodontitis (κ -coefficient = 0.44; $p = .004$).

PRCred and PRA4 risk categories fully matched in 30 patients (60%), the PRCred scored one category lower in six patients (12%) and two categories lower in one patient (2%) as compared with PRA4. By contrast, the PRA4 was rated one category lower in 11 cases (22%) and two categories lower in two cases (4%) (Figure 3b). The agreement between PRCred and PRA4 was only minimal (McHugh, 2012) (κ -coefficient = 0.23; $p = .13$). Depending on the SPT diagnosis, only a minimal level of agreement was

shown between PRA4 and PRCred according to severe periodontitis (κ -coefficient = 0.26; $p = .106$).

4 | DISCUSSION

In summary, the present study shows that two different methods for PRA, based on different risk factors, which make a statement about the progression probability of periodontitis, showed a minimal level of agreement. Nevertheless, in some cases, there were substantially different results for both risk assessment methods that the clinician should be aware of in daily routine.

As called for in a systematic review (Lang, Suvan, & Tonetti, 2015) and a more recent study (Ferraiolo, 2016) conducted on the topic of using risk assessment tools, the present investigation deals with the possible patient management implications of selected risk assessment methods. The two risk assessment tools presented here refer to thoroughly examined risk factors that have been evaluated in numerous long-term studies (Costa et al., 2012; Eickholz et al., 2008; Jansson & Norderyd, 2008; Lang & Tonetti, 2003; Leininger, Tenenbaum, & Davideau, 2010; Lu et al., 2013; Martin, Page, Loeb, & Levi, 2010; Matuliene et al., 2010; Meyer-Baumer et al., 2012; Page, Martin, Krall, Mancl, & Garcia, 2003). In addition, there are other risk assessment tools that are not discussed here (Chandra, 2007; Dhulipalla et al., 2015; Lindskog et al., 2010a, 2010b; Trombelli et al., 2017).

It has been shown that it makes sense to perform risk assessments in periodontally compromised patients in order to consider the individually different progression of the disease (Persson, Mancl, Martin, & Page, 2003). Differences between the two assessment tools chosen here exist in terms of the number of risk factors involved, the type of survey, and the weighing of individual factors. In this analysis, both risk assessment systems were used in two modifications. The original publication reporting PRA (Lang &

TABLE 3 Comparison for periodontal risk assessment categories of BOP for the assessment at 4 or 6 sites per tooth

			BOP (%)						Overall (%) 4 sites per tooth
			6 sites per tooth						
			Low risk		Moderate risk		High risk		
			≤4	5-9	10-16	17-24	25-35	≥36	
BOP (%) 4 sites per tooth	Low risk	≤4	3	2	0	0	0	0	5 (10)
		5-9	0	3	5	0	0	0	8 (16)
	Moderate risk	10-16	0	2	8	7	1	0	18 (36)
		17-24	0	0	1	8	2	1	12 (24)
	High risk	25-35	0	0	0	1	3	1	5 (10)
		≥36	0	0	0	0	0	2	2 (4)
Overall (%) 6 sites per tooth			3 (6)	7 (14)	14 (28)	16 (32)	6 (12)	4 (8)	50 (100)

Note: Agreements in risk categories are highlighted in grey.

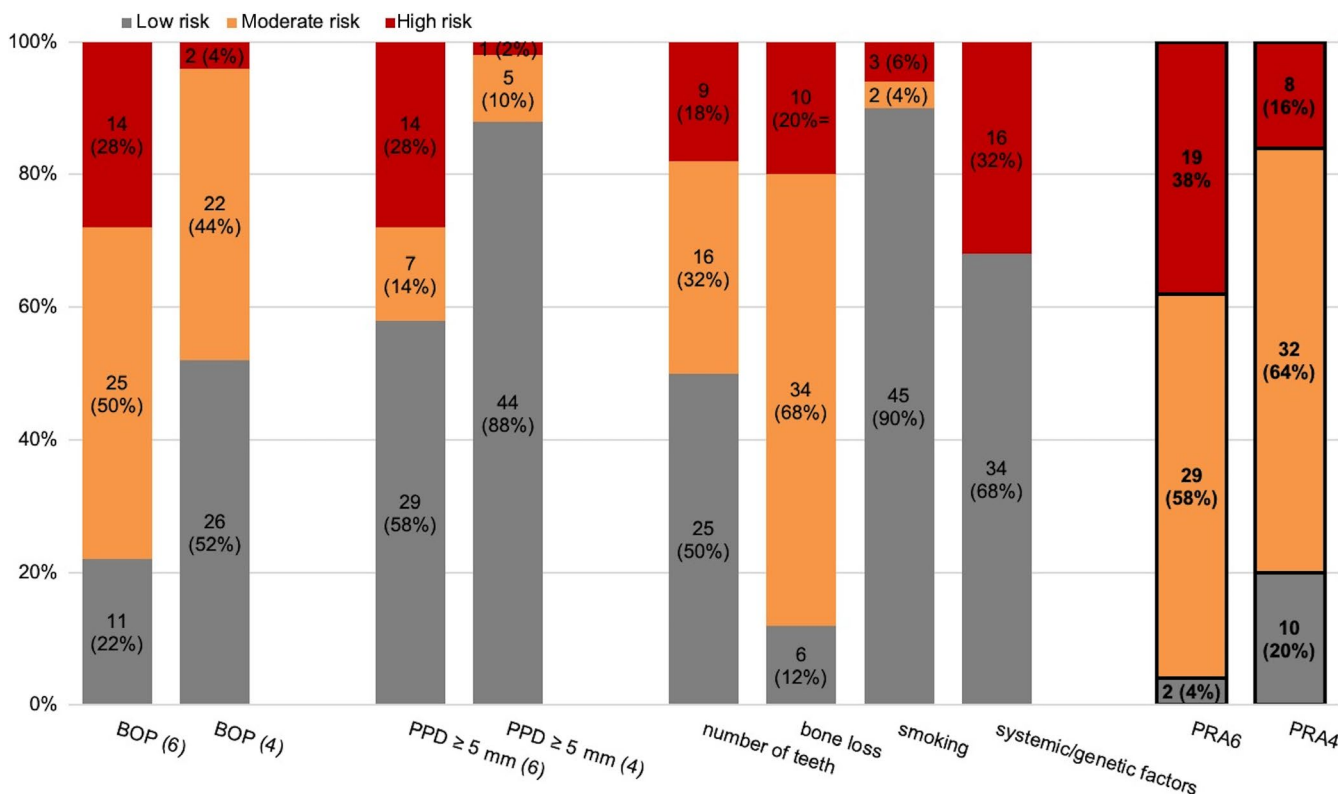


FIGURE 2 Relative distribution of risk categories (low, moderate, high) according to PRA assessed at 4 and 6 sites per tooth

Tonetti, 2003) does not define the number of sites measured for PPD or BOP. Matuliene et al. (2008,2010) measured PPD at 6 sites per tooth and scored BOP at 4 sites per tooth (Matuliene et al., 2008; 2010). Eickholz et al., 2008 assessed PPD and BOP at 6 sites per tooth (Eickholz et al., 2008). The same applies to the Department of Periodontology (Frankfurt/Main). Thus, we were able to quantify the changes in the PRA risk categories for four versus six sites per tooth. The difference of the evaluation standard had an effect on tooth-related parameters including number of sites with PPD ≥ 5 mm and BOP, whereas patient-related factors were not affected.

The scale of the PPD and BOP categories is principally different in the PRA.

PPD is represented as an absolute count, and BOP is represented as a relative frequency. Recording more sites will inevitably result in the same but, more likely, in higher frequencies and particularly higher absolute counts. Accordingly, change in the risk score in the PPD category was more pronounced compared with BOP. Moreover, recording of PPD at six sites per tooth included four inter-proximal measurement points instead of only two inter-proximal sites located at the buccal aspect of the tooth. Inter-proximal/oral sites are more

Risk category (4 sites per tooth)	Risk category (6 sites per tooth)			Overall (%) [4 sites per tooth]
	Low risk	Moderate risk	High risk	
Low risk	2	7	1	10 (20)
Moderate risk	0	22	10	32 (64)
High risk	0	0	8	8 (16)
Overall (%) [6 sites per tooth]	2 (4)	29 (58)	19 (38)	50 (100)

Note: Agreements in risk categories are highlighted in grey.

TABLE 5 The original five categories of PRC have been reduced (grouped) according to the PRA into three risk categories in order to be able to compare the two models

Risk category PRC	Risk category PRC reduced			Overall (%) [PRC]
	Low risk	Moderate risk	High risk	
Very low risk	0	0	0	0 (0)
Low risk	7	0	0	7 (14)
Moderate risk	0	8	0	8 (16)
High risk	0	23	0	23 (46)
Very high risk	0	0	12	12 (24)
Overall (%) [PRC reduced]	7 (14)	31 (62)	12 (24)	50 (100)

Note: Agreements in risk categories are highlighted in grey.

likely to have residual pockets than buccal sites. In general, the overall risk score showed higher scores for the PRA6 compared with PRA4 because more sites measured for PPD.

Moreover, these changes result from different measurement points of BOP, which, like PPD, are more often positive at inter-proximal/oral sites. The use of BOP in PRA is based partially on the research of Joss, Adler, and Lang (1994). These authors assessed BOP in a different way from the present study: "An individual BOP-index basing on the %s of the dichotomous scores was calculated. Inter-proximal sites were scored both from the buccal and the lingual aspects and hence, either aspect would contribute to a positive score" (Joss et al., 1994). This means that a positive inter-proximal BOP may result from buccal and/or oral probing. In clinical routine, BOP is scored after PPD assessment (Eickholz et al., 2008). Thus, PRA will depend upon whether the respective clinic/practice scores four or six sites per tooth. Due to time reasons, many practices may only score 4 instead of 6 sites. Thus, it is relevant to know the consequence for the risk assessment.

In contrast, comparison of the modifications of the PRC revealed no difference if the input field for "oral hygiene in need for improvement," "previous recall intervals irregular," and "scaling and root planing complete" was marked in the commercially accessible online platform (<http://www.previser.com>) or not. This suggests that these factors have no or only marginal impact on the underlying algorithm and the resulting classification of the patient. These three factors are not further defined in course of the survey. Unfortunately, PRC

TABLE 4 Accordance between periodontal risk assessment categories assessed at 4 and 6 sites per tooth

does not explain which criteria may be used to decide whether "oral hygiene (is) in need for improvement," "previous recall intervals (were) irregular," or "scaling and root planing (are) complete" or not. As compared with the other factors, they appear less objective and clear-cut and could therefore not be specified for patients included in our study. Risk classification is obscure and more arbitrary in this intransparent form. What amount of residual biofilm may be accepted or would be in need of improvement? As certain levels of BOP are associated with certain risk categories we would expect respective thresholds regarding, for example a plaque index. We may judge any Plaque Control Record (O'Leary, Drake, & Naylor, 1972) >0% as compatible with "oral hygiene in need of improvement." However, then only a very small minority of patients would fall into the category "no." "SRP completed" may mean both the termination of APT, but may also mean that there still remain deep pockets within the SPT, indicating that the SRP may never be completed for SPT patients with residual pockets. With regard to the "irregular recall" criterion, PRC may provide one of several existing definitions (Lee, Huang, Sun, & Karimbux, 2015). Due to the fact that PRC without defining criteria leaves the decision on "oral hygiene in need for improvement," "previous recall intervals irregular," and "scaling and root planing complete" to the therapist, we decided to either set all factor to "no" or all to "yes" in order to evaluate the effect of the maximally possible difference. However, both extremes did not make any difference. Thus, they may be omitted.

Comparison of PRA and PRCred demonstrated only a minimal correlation between both tools for risk assessment (PRA6-PRCred: κ -coefficient = 0.34; PRA4-PRCred: κ -coefficient = 0.23). However, considering the consistency of the two tools, depending upon the SPT diagnosis of patients according to the current classification of periodontal diseases (Tonetti et al., 2018), a weak agreement for patients with severe periodontitis ($n = 26$) was shown between PRA6 and PRCred (κ -coefficient = 0.44). Nonetheless, this could be an indication that better agreement is possible depending upon certain diagnoses or severity of the disease and specific risk factors (e.g., smoking). Basically, tools for scoring the individual periodontal risk on basis of accepted risk factors should result in a similar classification. What is the reason for the observed differences between PRA4/PRA6 and PRCred?

The commercial online version of the PRC considers 13 parameters, including two factors in addition to the originally described method (Page et al., 2002). In contrast, calculation of the PRA is

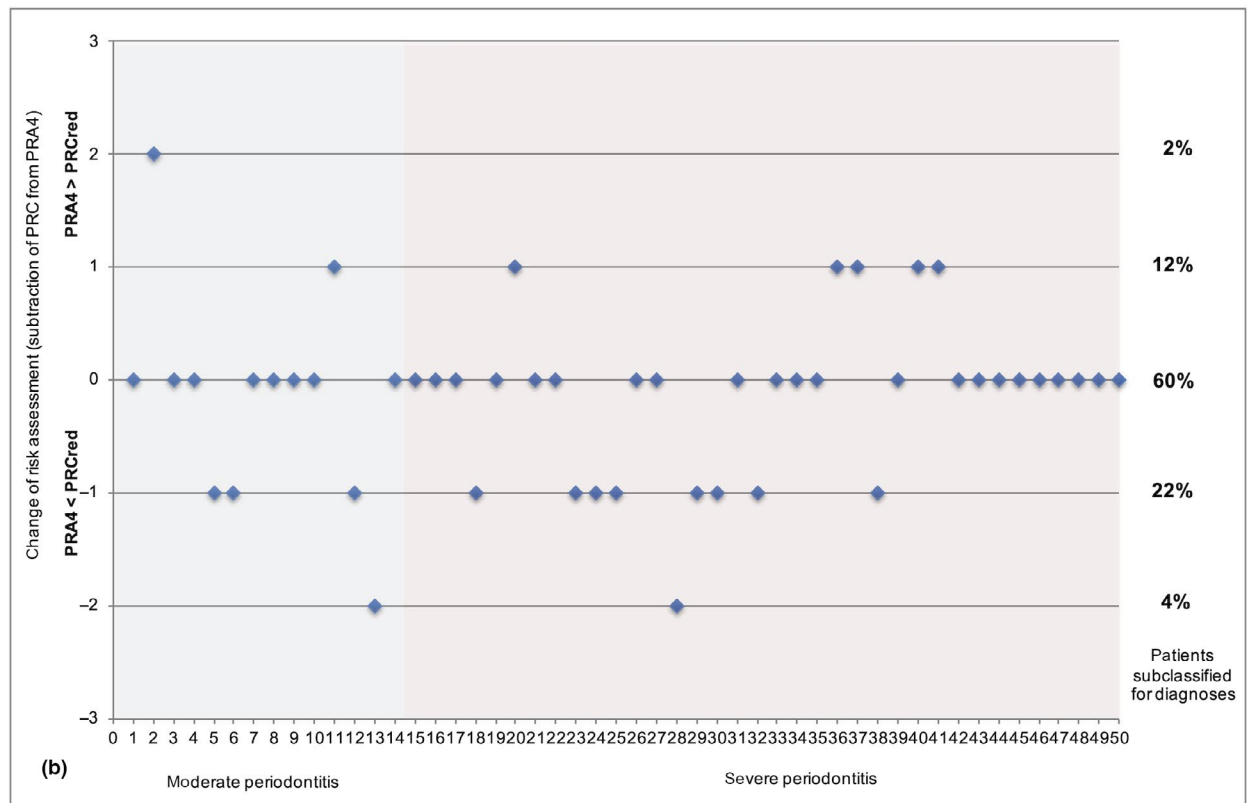
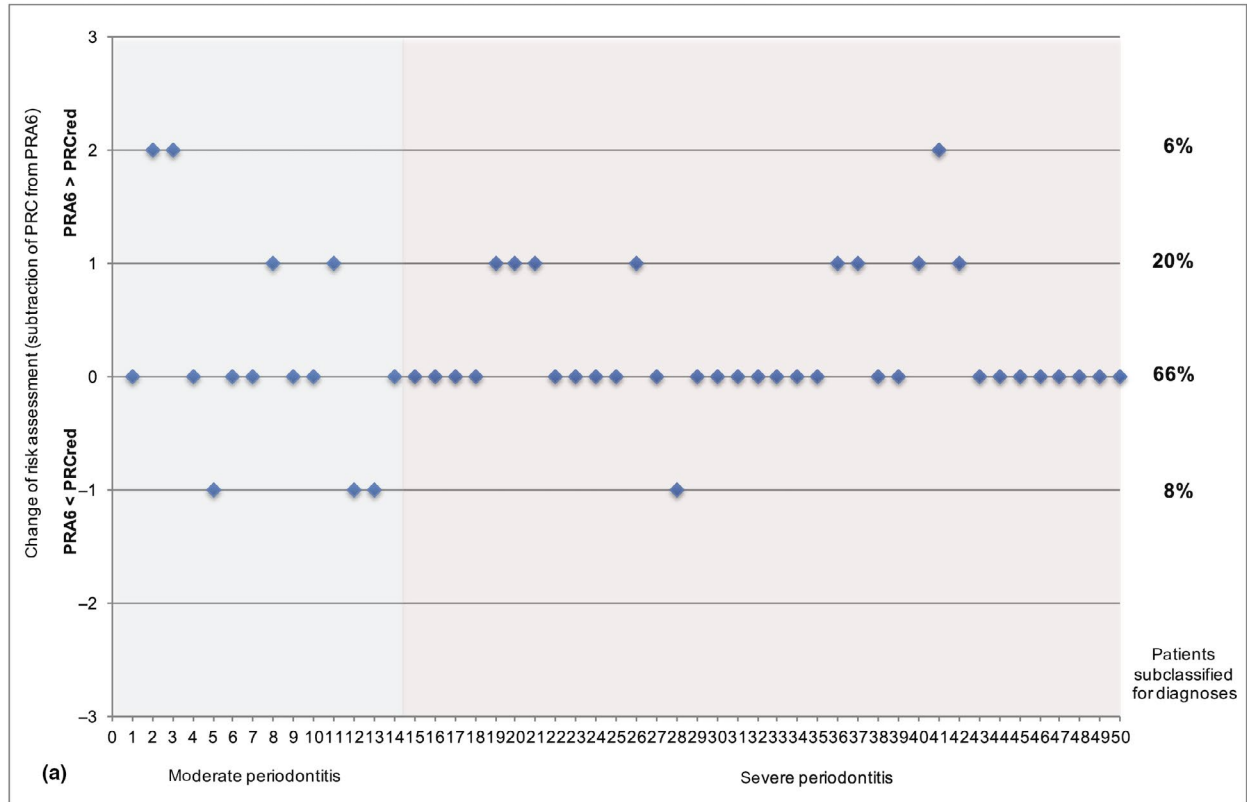


FIGURE 3 (a) change in the risk classifications when comparing PRCred with PRA6 at patient level subclassified according to the SPT diagnosis and (b) change in the risk classifications when comparing PRCred with PRA4 at patient level subclassified according to the SPT diagnosis

based on only six factors. However, the PRA includes more detailed information on PPD and BOP, which is recorded at several sites per tooth, whereas the PRC requires only a nominal information per sextant. In addition, the PRA takes into account risk factors such as tooth loss as well as genetic and systemic parameters that are not covered by the PRC. On the other hand, the PRC has a stronger focus on local risk factors such as the presence of FI, subgingival calculus and restoration margins. The PRA may provide this information indirectly and in greater detail via the absolute number of residual pockets, which may be increased or persist as a result of these local factors. The PRC reduces information about these local parameters to binary variables and does not reveal how they are included into the overall risk score.

The only known study comparing PRA with the PRC in a reduced form, as it was done in the present study, was conducted by an Indian working group (Sai Sujai et al., 2015). They reported a significant agreement ($p < .05$) among 57 patients, but these authors did not calculate any coefficient to quantify the agreement between both methods. Furthermore, the authors did not specify at how many sites per tooth PPD and BOP were recorded. These aspects limit the comparison of our data with the results reported by Sai Sujai et al. (2015).

Various studies have shown that regular SPT prevents tooth loss and positively influences periodontal stability. Therefore, patients who are regularly undergoing SPT may be assumed to have lower overall risk categories. However, this cannot be conclusively explained due to the unknown algorithm behind the PRC. The variable "irregular recall" did not influence the PRC outcome. The question of how to define "irregular recall" therefore does not need to be considered further.

Cohen's weighted kappa, as a measure of agreement between categorical scores, is subject to the classification used. In addition, it must be considered that, besides the division of kappa scores chosen here, there are other categorization options (Cicchetti & Sparrow, 1981; Fleiss, 1981; Landis & Koch, 1977; Viera & Garrett, 2005) that may allow for other interpretations. Further, the distribution of risk categories as categorical scores has a direct impact on the possible results of Cohen's weighted kappa. Therefore, in addition to purely statistical considerations, the consideration of the resulting clinical consequences is important.

While a transfer of the overall risk to corresponding SPT intervals has been described for PRA (low risk = 1 SPT/year, moderate risk = 2 SPT/year, high risk = 3–4 SPT/year), this is not yet available for the PRC (Eickholz et al., 2008; Matuliene et al., 2010; Ramseier & Lang, 1999). If the assignment of SPT intervals described by Ramseier and Lang for the PRA is applied accordingly to the PRCred risk categories in this study, different numbers of recall visits per year will result among the examined patients. Overall, risk assignment for the included 50 patients by PRA4 added up to 106 visits per year, or 136 visits using the PRA6 and 117 appointments per year using PRCred. In daily practice, this would have a significant impact on expenditure of time, organization and costs, particularly with higher numbers of patients. The question of which

tool for PRA is best for daily routine not only in a scientific context but also in terms of therapeutic consequences should be further addressed, with more emphasis in future studies. A classification of patients that relies only on the clinical experience of the practitioner may lead to overlooking patients' individual risk factors (Persson et al., 2003). The present study shows that the number of resulting appointments varies significantly. However, which modification reflects the risk of disease progression most accurately was not considered (Ferraiolo, 2016; Lang et al., 1986). A recommendation for or against one of the two systems cannot be made, even if the classification of the degrees of progression in the currently valid classification for periodontal diseases is much closer to PRA than to PRC (Tonetti et al., 2018). The question which risk assessment and SPT frequency will sustain periodontal health and prevent tooth loss may be investigated in randomized clinical trials. However, these studies have to include a high number of patients and cover observation periods of at least three years to detect changes in the clinical situation or tooth loss (Costa et al., 2012; Deinzer & Eickholz, 2018).

The absence of data on disease progression is a limitation of the study. Therefore, although this was not a primary issue of the study, no statement can be generated about the prognosis regarding disease progression. Thus, the validity of PRA and PRC cannot be judged. Furthermore, the collapse of risk categories in the PRCred is a limitation, which limits the comparability with already existing literature.

In addition, the small sample size, the different group size per SPT diagnosis and the assessment of subgingival RM on the basis of two-dimensional X-ray images are further limitations. Both PRA and PRCred were collected at different time points after completion of APT in patients with different baseline diagnoses, which may limit comparability due to the different influence of passed time.

5 | CONCLUSIONS

Within the limitations of this study, it was demonstrated that PRA and PRCred had only a minimal agreement and that the resulting overall risk partially differed considerably. Further clinical studies are needed to verify the agreement of the overall risk with the actual progression of periodontitis, in addition to the differences in classification established here.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests related to this study.

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