Assessment Criteria for Compliance with Oral Hygiene: Application of ROC Analysis

Hla Myint Htoon[a]/Lim Lum Peng[a]/Chan Yiong Huak[b]

Purpose: Diabetes is an established risk factor for periodontal disease. Management of periodontal disease is highly dependent upon effective oral hygiene. Assessment of plaque and gingivitis has been commonly used and arbitrarily set in clinical practice to evaluate patients' adherence with oral hygiene recommendations. This study aims to determine an objective cut-off criterion for assessing oral hygiene compliance utilising a combination of plaque and bleeding scores.

Materials and Methods: 161 patients with diabetes, from a prospective clinical trial, provided the clinical periodontal parameters at baseline to be used to determine the oral hygiene compliance criterion in relation to a composite score of pocket depth, subgingival calculus and supragingival calculus. A sequence of different combinations of plaque and gingival bleeding scores were used. Receiver operator characteristic (ROC) curve assessment, sensitivity, specificity, and predictive values were utilised for the determination of the criterion.

Results: The combination of 25% plaque scores and 15% gingival bleeding scores obtained the highest ROC value (using a probability cut-off of 0.5) of 0.868 with sensitivity 98.6%, specificity 75.0%, positive predictive value (PPV) 97.3% and negative predictive value (NPV) 85.7%. According to this criterion, amongst the cohort of subjects examined, 145 (90.1%) were categorised as non-compliant, and only 16 (9.9%) were considered compliant with oral hygiene at baseline.

Conclusions: Based upon the clinical periodontal parameters of subjects from this study, a combination of 25% plaque score and 15% bleeding score appears to be a valid target for determining compliance with oral hygiene in oral health programmes.

Key words: bleeding on probing, plaque, predictive values, oral hygiene compliance, receiver operator characteristics

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The association of poor oral hygiene with gingivitis and periodontitis has long been established (Löe et al, 1965; Axelsson and Lindhe, 1981; Haffajee et al, 1985). Improvement in oral hygiene practices has been shown to be associated with a concomitant improvement of periodontal status in terms of reduction in bleeding and gain in clinical attachment (Lovdal et al, 1961; Rosling et al, 1976; Nyman et al, 1977; Sheiham et al, 1986; Hugoson et al, 1998).

Diabetes has also been shown to be a major risk factor for periodontal disease progression (Löe, 1993; Grossi et al, 1994) manifested in the form of increased gingival inflammation (Cohen et al, 1970; Gislen et al, 1980; Grossi et al, 1994), increased probing pocket depth (PPD) (Bacic et al, 1988; Emrich et al, 1991; Tervonen and Oliver, 1993; Bridges et al, 1996) and calculus formation (Tervonen and Oliver, 1993; Tervonen and Karjalainen, 1997).

Compliance with oral hygiene is often used as a yardstick for determining the effectiveness of oral health promotion programmes. The outcome has been evaluated through various approaches, such as verbal feedback or self-reporting of improved oral hygiene practices, self-monitoring of oral hygiene and clinical

[a] *Preventive Dentistry Department, Faculty of Dentistry, National University of Singapore, Singapore*

[b] *Yong Loo Lin School of Medicine, Clinical Research Centre, 10 Medica Drive, Singapore*

Reprint requests: *Dr. Hla Myint Htoon, Preventive Dentistry Department, Faculty of Dentistry, National University of Singapore, 5 Lower Kent Ridge, Singapore 119704. Tel: (65) 91857550. Fax: (65) 67745701. Email: htoonhm@gmail.com*

observation of a reduction in plaque and gingival inflammation scores.

While verbal or written feedback has been partially useful in evaluating compliance, more objective measures have been advocated in the clinical setting. Plaque and bleeding on probing (BOP) assessment are perhaps the most common clinical assessment criteria used to evaluate an individual compliance with oral hygiene self-care. It is generally accepted that the use of a single parameter, such as plaque score alone, to determine compliance with oral hygiene would not be adequate as an individual may not necessarily be consistent in achieving a good standard of plaque control at all times. A low plaque score could still be achievable if the individual cleans his teeth diligently just before the dental examination. The use of a combination of plaque and bleeding scores are therefore preferred as being more objective and reflective of sustained behavioural change (Abbas et al, 1986; Lim, 1991). Arbitrary levels of acceptable scores have been set by different investigators, varying from a threshold value ranging from 10–25% plaque score and 10–20% bleeding scores (O'Leary, 1972; Isidor et al, 1984; Lindhe et al, 1989; Kaldahl et al, 1990; de Abreu et al, 2002). The combined criterion however has not been objectively tested in relation to predictability with progression of periodontal disease.

BOP by itself was reported to have a high negative predictive value (NPV) of 98% with a low positive predictive value (PPV) of 6%. While BOP may not be a sensitive predictor of disease progression, the absence of BOP was deemed a good indicator of periodontal stability, as demonstrated by Lang et al (1990).

Badersten et al (1990) showed that diagnostic predictability of attachment loss (AL) peaked at 30–75% plaque and concluded it has limited value as a predictor for AL. Similarly the mean percentage of BOP peaked at 30% and therefore limits its predictive capacity. Similar findings were also reported by Claffey et al (1990). However, Joss et al (1994) found that two-thirds of sites with AL were associated with BOP ≥ 30%, indicating a three-fold increase in risk as compared with one-fifth of sites with AL when BOP was ≤ 20%.

Renvert and Persson (2004) found that the percentage of plaque was only significantly associated with bone loss at the lower end range of between 10–20% bone loss, beyond which no significant association was shown. In the same study, the percentage of BOP failed to demonstrate any consistent association with alveolar bone loss at all levels. In summary, the findings highlight the limitations of plaque score or BOP when used alone as predictors for periodontal disease progression (Lindhe et al, 1989; Badersten et al, 1990; Kaldahl et al, 1990; MacGuire and Nunn, 1997). To date, the evidence for an optimal level of plaque combined with bleeding as a measure of compliance with oral hygiene has not been objectively evaluated in relation to other periodontal disease parameters.

To determine the optimum cut-off level of a diagnostic test or criteria, a classic trade-off between sensitivity (Sn) and specificity (Sp) is often involved. For such purposes, receiver operator characteristic (ROC) plots have been found to be a useful tool in clinical decision making in health sciences (Zweig and Campbell, 1993). A ROC curve involves a plot of pairs of sensitivity (true positive rate) and '1-specificity' (false positive rate) for a given cut-off value of a diagnostic test or parameter. To compare the usefulness of the tests, the ROC curve with the larger area under the curve is considered the better or more accurate option. The advantage of ROC analysis is that positive and negative predictive values are independent of the prevalence of the problem (Obuchowski, 2003). In dentistry, ROC analyses have been found to be useful in: caries diagnosis (Verdonschot et al, 1993; Hintze et al, 2003); endodontics (Syriopoulos et al, 1999); restorative decision making (Kay and Knill-Jones, 1992; Holmes et al, 2001); oral surgery (Loesche et al, 1997; Nair et al, 2000); and periodontal risk assessment (Mombelli et al, 2002; Persson et al, 2002; Renvert and Persson, 2004; Yamamoto et al, 2005; Persson et al, 2005). To date there is no observed report utilising ROC analysis in determining compliance with oral hygiene.

The purpose of this study was to determine an objective cut-off criterion for assessing oral hygiene compliance based upon a combination of plaque and bleeding scores utilising the ROC curve.

MATERIALS AND METHODS

Subjects of the study comprised 161 subjects diagnosed with Type I or Type II diabetes who were enrolled in a periodontal intervention study. Prior to the study, ethical approval was obtained from the Internat Review Board. The baseline periodontal parameters for the subjects were used to explore an optimal level of oral hygiene for the target population. The participating subjects included both males and females aged 21–65 years from three different ethnic groups and without other major medical complications. A full mouth assessment of clinical parameters on mean PPD, mean percentage plaque, mean percentage BOP, mean percentage of supragingival and subgingival calculus were recorded by two examiners at baseline. Assessments of plaque, BOP and calculus were based on

absence and presence criteria. Probing depths were measured to the nearest mm using the UNC (University of North Carolina) probe with 1 mm graduation markings. These clinical data were utilised for the ROC assessments. Subjects were randomly chosen, without any prior instructions on oral hygiene.

The minimum cut-off points for a sequence of different combinations of plaque and bleeding scores (BOP) were used in the analysis: 30% plaque in combination with 25% BOP (30-25); 30% plaque and 20% BOP (30-20); 30% plaque and 15% BOP (30-15); 25% plaque and 25% BOP (25-25); 25% plaque and 20% BOP (25-20); 25% plaque and 15% BOP (25-15); 20% plaque and 25% BOP (20-25); 20% plaque and 20% BOP (20-20); 20% plaque and 15% BOP (20-15) and finally 15% plaque in combination with 15% BOP (15-15).

These various combinations of plaque and bleeding scores were assessed against a composite model that combined the mean PPD, mean percentage of supragingival calculus and mean percentage of subgingival calculus.

ROC curve assessments and binary logistic regression were carried out using SPSS 11.5 software.

RESULTS

In the analysis of ROC, the area under the curve was estimated as well as the Sn, Sp, PPV and NPV.

A composite model, which included mean PPD and mean percentage of supragingival and subgingival calculus, provided good diagnostic properties. The justification for using these parameters is that these variables are plaque retention factors and may also be reflective of periodontal disease severity. It must be noted that oral hygiene compliance is considered a surrogate endpoint for change in behaviour in relation to gingival host response.

Using the range of combined plaque and BOP scores (30-25, 30-20, 30-15, 25-25, 25-20, 25-15, 20-25, 20-20, 20-15), the highest ROC curve estimate was obtained for 25-15 (25% plaque and 15% BOP), with a value of 0.868 (95% CI 0.740–0.996) and the next highest ROC score was found for 20-15 (0.843, 95% CI 0.689–0.996). The respective Sn, Sp, PPV and NPV values for the 25-15 level were 98.6, 75.0, 97.3 and 85.7, compared with Sn 99.3, Sp 69.2, PPV 97.3, and NPV 90.0 for 20-15.

The ROC curves for selected combination of scores are displayed in Fig 1. Table 1 shows the different range of plaque and BOP levels used as criterion cut-off levels with ROC assessments. Table 2 shows the respective Sn, Sp, PPV, and NPV values.

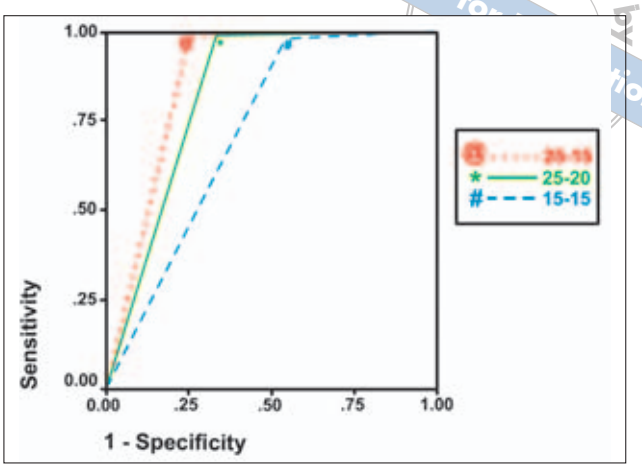

Fig 1 ROC curve analysis of oral hygiene compliance. Diagonal segments are produced by ties.

Based upon the cut-off criterion at 25% plaque and 15% BOP (25-15), 145 subjects were categorised as non-compliant (90.1%, 95% CI 85.5–94.7%), and only 16 (9.9%, 95% CI 5.3–14.5%) were considered compliant with oral hygiene at baseline. Subgroup analysis by Pearson's Chi Square test did not reveal any significant differences among the ethnic groups (Table 3) or the various age categories (Table 4). Similarly, no differences were found between males and females, or those with good and unacceptable glycaemic control.

In summary, the cut-off level 25-15 showed the highest ROC estimate with a correspondingly high Sn, Sp, PPV and NPV. The cut-off level 20-15 which showed the second highest ROC estimate also demonstrated good diagnostic and predictive values.

Table 1 ROC: area under the curve assessment from different oral hygiene cut-off levels (p < 0.5)

Cut-off	A_z (area under the curve)	95% Confidence interval
30-25	0.714	0.590–0.839
30-20	0.738	0.611–0.865
30-15	0.743	0.610–0.875
25-25	0.758	0.625–0.892
25-20*	0.830	0.695–0.964
25-15***	0.868	0.740–0.996
20-25	0.723	0.575–0.871
20-20	0.797	0.641–0.952
20-15**	0.843	0.689–0.996
15-15	0.717	0.523–0.912

****highest, **second highest, *third highest cut-off levels (combination of % plaque-%BOP)*

Table 2 Sensitivity (Sn), specificity (Sp), positive predictive value (PPV), and negative predictive value (NPV) from different oral hygiene compliance cut-off levels

Cut-off	Sn	Sp	PPV	NPV
30-25	94.7	48.1	90.7	65.0
30-20	95.6	52.0	91.5	68.4
30-15	96.4	52.2	92.3	70.6
25-25	97.1	54.5	93.1	75.0
25-20*	99.3	66.7	95.9	92.3
25-15***	98.6	75.0	97.3	85.7
20-25	97.2	69.2	93.2	69.2
20-20	99.3	90.0	96.0	60.0
20-15**	99.3	69.2	97.3	90.0
15-15	98.0	62.5	96.1	45.5

****highest, **second highest, *third highest cut-off levels (combination of %plaque-%BOP)*

Table 3 Comparison of oral hygiene compliance (25-15) at baseline by ethnicity

	Oral hygiene compliance (25-15)			Pearson's Chi Square test
	Acceptable (%)	Unacceptable (%)	Total	Asymptotic significance
Chinese	12(10.1)	107(89.9)	119	0.970
Malay	2(11.8)	15(88.2)	17	
Indian	2(8.3)	22(91.7)	24	
Others	0	1(100)	1	

Table 4 Comparison of oral hygiene compliance (25-15) at baseline by age groups

	Oral hygiene compliance (25-15)			Pearson's Chi Square Test
Age (years)	Acceptable (%)	Unacceptable (%)	Total	Asymptotic significance
21–40	4 (8.0)	46 (92.0)	50	0.648
41–55	7 (9.8)	68 (90.2)	75	
56–65	5 (13.9)	31 (86.1)	36	

DISCUSSION

To determine the oral hygiene compliance of individuals, acceptable levels of plaque and bleeding scores have historically been arbitrarily set. It is obvious that the use of plaque score alone does not necessarily reflect the consistency in self performed oral hygiene. Furthermore, in a plaque re-growth study, it has been demonstrated that plaque could be detected as early as 3 hours after cleaning, even more so in the presence of a sucrose-supplemented diet (Lim et al, 1986). Although the use of BOP may not necessarily be a good predictor of AL, it is a good indicator of periodontal stability (Badersten et al, 1990; Lang et al, 1990). A combination of plaque and bleeding scores appears a more appropriate measure of oral hygiene compliance. In view of the fact that not all patients are equally susceptible to periodontal disease despite the presence of plaque, some authors have advocated the use of BOP to plaque ratio (van der Velden et al, 1985; Abbas et al, 1986; Sastrowijoto et al, 1990). By combining the two variables – the host response (as measured by BOP) in relation to plaque levels (plaque score) – it could serve as a means to identify the level of susceptibility to gingival inflammation. However, this has not been shown to be a good indicator or predictor for periodontal disease progression due to the inherent limitations in calculating the ratio. For example, if a

bleeding/plaque ratio of 0.5 is used to depict low susceptibility, it merely reflects that the bleeding score is half that of the plaque score. An individual with a 50% BOP and 100% plaque would give the same ratio as an individual with 10% BOP and 20% plaque, while in reality the interpretation of the risk is obviously higher in the former case. Galgut (1988) noted that the relationship between BOP and plaque could be improved before being used as a predictor for the likelihood of good gingival health.

The ROC curve has been commonly used to evaluate the reliability of diagnostic tests. ROC values of 0.8 and above are considered good estimates, as demonstrated in the present study. Besides a high ROC estimate, the respective Sn, Sp, PPV and NPV should also be high. The current study is one of the first attempts to explore the utility of ROC in defining an appropriate optimal level of plaque and bleeding scores as a measure of compliance with oral hygiene. The use of a gold standard is a prerequisite in assessing the ROC curve; however, in the absence of such a gold standard, the use of common periodontal parameters such as probing depths and calculus appear to be appropriate determinants of periodontal disease. The present ROC area estimates were highest at 25-15 (plaque 25%, BOP 15%), followed closely by 20-15 (plaque 20%, BOP 15%), with a correspondingly high PPV and NPV. Adhering to the lower level cut-off at 20-15, 15-15 also yielded excellent predictive values; these could also be accepted as an alternative to 25-15. However, 25-15 should be considered the minimum acceptable threshold level compatible with health; it is perhaps less stringent than the other categories and would be more applicable and achievable in clinical settings.

As the present model is based upon an estimation of the baseline characteristics in the cohort of patients with diabetes under consideration, the findings may not necessarily be applicable to other patient groups. To test objectively for an optimal cut-off level for different categories of periodontal patients, separate ROC analysis may be required. Since patients with diabetes have been shown to have more severe periodontal breakdown and a higher susceptibility to gingival inflammation (Soskolne and Klinger, 2001; Salvi et al, 2005), it is possible that a less stringent criterion may be required for patients with low risk to periodontal disease. Conversely, an even more stringent cut-off level may be needed for patients in the very-high-risk category. The present oral hygiene compliance criterion has shown that the present study cohort is relatively homogenous based on age categories and ethnic groups; therefore it provides sound baseline data to compare the effects of intervention in a longitudinal study. Even with the limitations, this study confirms that some of the commonly recommended targets of plaque control with oral hygiene programmes appear applicable and justified in the current context.

CONCLUSIONS

Within the confines of this study, a combination of 25% plaque score and 15% BOP (25-15) obtained the highest ROC value with high Sn, high PPV and moderate Sp and NPV. This threshold level could be considered a valid goal for patients in plaque control programmes. As a cut-off level, individuals presenting with a combination of ≥ 25% plaque score and ≥ 15% BOP would be considered non-compliant and would need further reinforcement in oral hygiene. Therefore the cut-off value could also be used to compare patient's response to periodontal intervention programmes and to monitor patients' compliance with oral hygiene during maintenance care.

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