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Clinical attachment loss: estimation by direct and indirect methods

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Objective: This observational study aimed to compare the estimation of clinical attachment loss (CAL) as measured by direct (CAL_D) and indirect (CAL_I) methods. **Methods:** Periodontitis patients ($n = 75$; mean age: 50.9 ± 8.02 years; 72.2% women; 50.6% smokers) received a periodontal examination (six sites/tooth) to determine the presence of visible plaque and calculus, the gingival bleeding index (GBI), periodontal probing depth (PPD), bleeding on probing (BOP), CAL_D and gingival recession (GR). CAL_I values resulted from the sum of PPD and GR values. Statistical analysis considered only data from sites with visible GR (e.g. the gingival margin apical to the cemento–enamel junction; $n = 4{,}757$ sites) and determined the mean difference between CAL_I and CAL_D measurements. Based on the mean difference, univariate and multivariate analyses were also performed. **Results:** Mean CAL_D and CAL_I values were 3.96 ± 2.07 mm and 4.47 ± 2.03 mm, respectively. The indirect method overestimated CAL compared with the direct method (mean difference: 0.51 ± 1.23 mm; $P < 0.001$). On uni- and multivariate analyses, absence of GBI and BOP, PPD and proximal site location had significant influences on the overestimation of CAL by the indirect method (all $P \leq 0.01$). The indirect method increased the CAL value by 0.38 mm for each additional 1 mm in PPD. **Conclusions:** To decrease the number of probing errors in daily practice it is suggested that direct examination is more appropriate than the indirect method for estimating CAL.

Key words: *Periodontal disease, dental practice, diagnosis*

INTRODUCTION

During periodontal probing, errors can correspond to 30–50% of the final estimated value[1–5]. As such, several publications have focused on evaluating periodontal probing from a methodological perspective by investigating the sources of errors; these could be related to the type and the thickness of the probe[6,7], examiner characteristics[8], applied force[9–11], need for stents[12] and use of onlays[13]. Other studies have examined errors in the examination process from the perspective of intraoral conditions, such as inflammatory status[10,14–16], the presence of supragingival[17] and subgingival calculus[18] and tooth position in the arch[2]. Nevertheless, there is consensus that besides these issues related to the methodology and the clinical conditions, the definition of how the parameter will be collected during the periodontal examination will impact the final measurement, regardless of whether this is an indicator of inflammation [e.g. periodontal probing depth (PPD)], or destruction [e.g. clinical attachment loss (CAL) or gingival recession (GR)].

To illustrate, in the absence of GR [i.e. when the gingival margin is coronal to the cemento–enamel junction (CEJ)], CAL is commonly measured by subtracting the distance between the CEJ and the free gingival margin (FGM) from the PPD value[1,5]. On the other hand, in the presence of GR, although it is still possible to measure the extent of CAL directly (CAL_D) by visualisation of the probe over the reference point, some authors choose to measure it indirectly: the CAL (CAL_I) from the sum of the PPD and GR values[5,19–21]. However, from a mathematical standpoint, because both PPD and GR are subject to measurement errors, their combined use to determine the CAL_I could lead to the compounding of errors that could interfere with the final CAL value[5,22].

Even though the errors introduced by the combination of two different probing measures can be diluted

when the data are aggregated in an average (e.g. an average result of sites nested within teeth, nested within individuals or nested within a sample), attempts to reduce the errors inherent to the periodontal probing measurements are still a valid concern. This observation is genuine, as reproducibility of the examiners' periodontal measurements remains an important step in clinical investigations, regardless of whether or not it is epidemiological[3,13,23–25]. However, to the best of our knowledge, as recently as 2013, a comparison between the direct and indirect methods for measuring CAL during the reproducibility process was first discussed in the literature[17]. CAL_D and CAL_I measurements were performed by the same examiner within a 1-week interval in periodontal patients, and the results were compared; Corraini *et al.*[17] reported that the direct method was preferable to the indirect method because the CAL_D method showed fewer errors in reproducibility. This finding confirms and increases the concern about the impact of the indirect method on the estimation of CAL during routine periodontal examinations, especially because the existence and/or the degree of this error are still unreported.

The aims of the present study were to compare the magnitude of the values of CAL_D and CAL_I and to determine whether these methods are influenced by periodontal clinical variables. The hypothesis was that there would be a significant difference between the CAL_D and CAL_I values.

METHODS

Study design and sample

This study was an observational secondary investigation. The sample was composed of subjects participating in an ongoing randomised clinical trial (RCT) (NCT #01598155) that was approved by the Ethics Committee of the Federal University of Rio Grande do Sul (UFRGS; #18917) and conducted in accordance with the Declaration of Helsinki. All participants received verbal and written information about the study protocol and signed an informed-consent form.

To participate in the primary RCT, the participants were selected from a convenience sample of patients, referred to the Dental School of UFRGS between May 2012 and September 2013 for periodontal treatment, according to the following inclusion criteria: minimum age 35 years; having at least 12 teeth; a diagnosis of moderate-to-severe periodontitis[26]; absence of systemic conditions that could influence the periodontal status (e.g. diabetes, pregnancy, cardiovascular disease with need for antibiotic use); and absence of an orthodontic appliance.

No intervention was performed in the present study. The data used herein were related to the clinical periodontal examination of the patients included in the primary RCT ($n = 75$). The demographic characteristics of the sample are described in *Table 1*.

EXPERIMENTAL PROCEDURES

Examiner calibration

The reproducibility process included PPD, CAL_D and GR indicators. Three examiners were involved in this investigation. Two examiners (P.D.M.A. and A.F.S.) performed the PPD and CAL_D examinations. The third examiner (V.L.B.) was responsible for the measurements of PPD and GR. Thus, each examiner performed only the direct or the indirect method for measuring CAL. This was undertaken to avoid a memory bias during the measurements. During the exercise, each examiner performed 10 full-mouth duplicate examinations. *Table 2* shows the intraclass correlation coefficient (ICC) values for intra- and inter-examiner reproducibility.

Data collection

To record the periodontal condition, a 15 mm North Carolina periodontal probe (UNC; Neumar Ltda., Pirituba, SP, Brazil) was used. All erupted permanent teeth, excluding the third molars and implants, were examined at six sites corresponding to the mesio-buc-

Table 1 Demographic characteristics and clinical periodontal measures of patients in the study sample ($n = 75$)

Variable	Value
Demographic characteristics	
Age (years)	50.9 ± 8.02
Gender (female)	72.2
Smokers	50.6
Number of teeth	21.97 ± 4.19
Clinical periodontal indicators*	
VPI†	40 ± 0.49
GBI†	14 ± 0.35
Calculus†	19 ± 0.39
BOP†	30.10 ± 0.46
PPD (mm)	2.42 ± 1.21
CAL_D (mm)	3.96 ± 2.07
CAL_I (mm)	4.47 ± 2.03
'*d* value' (mm)	0.513 ± 1.23

Values are given as mean ± standard deviation or as a percentage. BOP, bleeding on probing; CAL_D, clinical attachment loss measured using the direct method; CAL_I, clinical attachment loss measured using the indirect method; '*d* value', difference between CAL_I and CAL_D measurements; GBI, gingival bleeding index; PPD, periodontal probing depth; VPI, visible plaque index.
*Data only for sites with gingival recession ($n = 4$, 757) from patients in the study sample ($n = 75$).
†Percentage of positive sites.

Table 2 Intraclass correlation coefficient values of intra- and interexaminer reproducibility

	PPD	CAL_D	GR
Intra-examiner 1	0.93	0.91	–
Intra-examiner 2	0.93	0.93	–
Intra-examiner 3	0.89	–	0.97
Interexaminer	0.87	0.91	–

CAL_D, clinical attachment loss measured using the direct method; GR, gingival recession; PPD, periodontal probing depth.

cal, mid-buccal, disto-buccal, mesio-lingual, mid-lingual and disto-lingual areas. The following indicators were assessed: visible plaque index (VPI) and gingival bleeding index (GBI)[27]; the presence of calculus; PPD; bleeding on probing (BOP); CAL_D; and GR. PPD was defined as the distance from the FGM to the bottom of the clinical pocket. CAL_D was defined as the distance between the CEJ and the bottom of the clinical pocket. GR was defined as the distance between the CEJ and the FGM. CAL_I was obtained by summing the PPD and GR values. All of these measurements were obtained in millimeters and were rounded up to the nearest millimeter. In the presence of restorations and/or dental prostheses overlapping the CEJ, the restorative margin was the reference. VPI, GBI, presence of calculus and BOP were dichotomous variables considered as either present or absent and were collected only by P.D.M.A. and A.F.S., who were previously trained for these evaluations. An assistant recorded data on prepared record sheets. These data were then transferred into electronic data files. In sequence, the computer data files were checked for typographical errors by comparison with the original data sheets.

Data analysis

From a total of 9,888 sites examined, only sites with GR (n = 4,757) were considered in the statistical analysis. The normality of data distribution was checked using the Kolmogorov–Smirnov test. Means and standard deviations (±SD) for PPD, CAL_D, GR and CAL_I, and the percentage of positive sites (±SD) for VPI, GBI and calculus were calculated for each patient and then for the total sample. The mean difference between CAL_I and CAL_D measurements was termed the '*d* value', and it was considered as the primary outcome. The comparison between the mean CAL_D and CAL_I values was performed using the paired Student's *t*-test.

Mixed models were used for univariate and multivariate analyses, taking the site as the analysis unit. The dependent variable was the '*d* value'. The independent variable, type of sites, was categorised into 'free sites', corresponding to the buccal and lingual surfaces, or 'proximal sites', corresponding to the mesio-buccal, disto-buccal, mesio-lingual and disto-lingual surfaces. No interaction was found between the independent variables.

The SPSS Statistics v.21.0 software package (SPSS Inc., Chicago, IL, USA) was used to perform the statistical analyses. The level of significance was set at 5%.

RESULTS

Table 1 shows the periodontal indicators examined at sites with gingival recession (n = 4,757) in the present sample (n = 75 patients). The mean CAL_I value was higher than the mean CAL_D value. According to the '*d* value', the indirect method overestimated the periodontal destruction by a mean of 0.5 ± 1.22 mm compared with the direct method. This difference was statistically significant ($P < 0.001$). Based on this primary outcome, the study power to detect a difference between the CAL_I and CAL_D variables at a significance level of 5% was calculated to be 94.7%. When the CAL estimation was analysed, according to PPD categories, as shallow (PPD ≤ 4 mm) and deep (PPD > 4 mm) sites, overestimation by the CAL_I method was 0.44 ± 1.14 mm for shallow sites and 0.97 ± 1.58 mm for deep sites.

Table 3 presents the results of the univariate and multivariate analyses related to the dependent variable '*d* value'. In univariate analysis, the variables GBI, BOP, PPD and type of site exerted significant influence on the '*d* value' ($P < 0.01$). All variables that reached statistical significance in the univariate model (GBI, BOP, PPD and type of site) remained significant in the multivariate model ($P \leq 0.001$). When CAL was measured using the indirect method, every 1-mm increase in PPD resulted in an overestimation in the CAL of 0.378 ± 0.016 mm (*Table 3*).

DISCUSSION

In the present study, by comparison with CAL_D, CAL_I overestimated periodontal destruction when used to measure the clinical attachment loss. This overestimation was influenced by the PPD value and increased significantly when bleeding was absent and measurements were performed at proximal sites.

Recently, Corraini *et al.*[17] compared the measurement errors associated with CAL_D and CAL_I. They showed that the direct method of measuring CAL was preferable to the indirect method because it had better reproducibility. The present study provided information on the extent to which CAL_I may be overestimated. The overestimation of CAL_I observed here, of 0.5 mm, might be related in the accumulation of well-known errors inherent in periodontal probing because

Table 3 Results of the mixed models: univariate and multivariate analysis*

Variable	Univariate analysis			Multivariate analysis		
	'*d* value' ± SE	Effect	*P*-value	'*d* value' ± SE	Effect	*P*-value
VPI						
Present	0.497 ± 0.052					
Absent	0.500 ± 0.048	0.003	0.940	–		–
GBI						
Present	0.325 ± 0.065			0.281 ± 0.062		
Absent	0.529 ± 0.045	0.204	<0.001	0.457 ± 0.045	0.177	0.001
Calculus						
Present	0.517 ± 0.060					
Absent	0.495 ± 0.046	–0.025	0.654	–		–
BOP						
Present	0.313 ± 0.052			0.139 ± 0.054		
Absent	0.582 ± 0.045	0.268	<0.001	0.600 ± 0.050	0.461	<0.001
Site						
Proximal	0.544 ± 0.048			0.517 ± 0.051		
Free	0.452 ± 0.048	–0.092	0.008	0.221 ± 0.050	–0.296	<0.001
PPD						
Millimeter	0.266 ± 0.015		<0.001	0.378 ± 0.016		<0.001

BOP, bleeding on probing; CAL_D, clinical attachment loss measured using the direct method; CAL_I, clinical attachment loss measured using the indirect method; '*d* value', difference between CAL_I and CAL_D measurements; GBI, gingival bleeding index; PPD, periodontal probing depth; SE, standard error; VPI, visible plaque index.
*Data only for sites with gingival recession (n = 4,757) of patients in the study group (n = 75).

the indirect method is based on the sum of two recordings (PPD and GR) to obtain the final value (CAL_I)[2–4,6,9,22]. It is believed that this overestimation may be a result of the combination of two measures that are also subject to errors. Furthermore, these errors can also be associated with a large number of variables related to the anatomy (e.g. crown curvatures, root angulations, presence of caries or restorations and morphology of the bone defects)[2,3], the examiner's experience (e.g. probing force, pain provoked by probing and time available for probing)[8,25], probe design (e.g. probe thickness and angulation, and manual or automatic probe)[7,11], the clinical periodontal status (e.g. tonus of the gingiva and the strength of epithelial attachment, presence of calculus, presence of gingival recession and mobility of the tooth)[10,14–17] and others. Notwithstanding, an additional source of error may be associated with the fact that manual probes do not provide an exact decimal measure, leading to the usual 'rounding' to the next entire (upper or lower) millimeter.

In this sense, this investigation also tried to verify which clinical indicators in the present sample could be influencing the overestimation. Thus, uni- and multivariate models were used to evaluate how the '*d* value' was related to the presence of supragingival plaque and calculus, bleeding on probing, periodontal pocket depth and the location of the surface being probed. Considering independent variables individually, the univariate analysis showed the difference between the direct and indirect methods as significantly influenced by the presence of GBI and BOP, higher PPD values and measurements at proximal sites. The significant associations were maintained even when all variables were considered together, in the multivariate model.

According to the literature, greater PPD leads to a higher chance of error in CAL measurement[5,28], the extent of which is illustrated herein. The overestimation of 0.38 for each millimeter increase in PPD is probably the result of two factors: the greater PPD value per se; and the measurement of PPD and GR separately. These findings are particularly important in the clinical management of periodontal patients: the overestimation of CAL at sites with higher PPD values may represent considerable impairment to the diagnosis process.

The presence of inflammation is important, particularly for greater probing-depth measurements[17,29,30]. In the present study, the indirect method generated higher estimations of CAL compared with the direct method, regardless of whether or not the site was inflamed. However, the overestimation was even higher for non-inflamed sites (i.e. GBI- and BOP-negative sites). One explanation for this last finding could be a bias introduced by the limited number of sites showing GBI (14% or n = 666) and BOP (30% or n = 1,431). Adding to this, half of the participants in the study sample were smokers and therefore the smoking habit might be acting as a confounding factor[19,20]. However, when smoking status was included in the uni- and multivariate analysis, it did not influence the CAL estimation (data not shown). Nevertheless, it is not feasible to perform a stratified analysis here, and this issue would be better explored in future studies.

Anatomical factors, such as the location of the site around the tooth (and especially differences in the crown curvature and root angulations), have also been implicated in the generation of errors during probing measurements[2,3,13]. In this sense, to verify the impact of the site variable in the CAL measurements made by both methods, the sites were categorised as free or proximal, and this variable was included in the uni- and multivariable analysis. As a result, the proximal sites were significantly associated with greater CAL overestimation by the indirect method compared with the free surfaces. This result is similar to those reported by Badersten *et al.*,[13] Grossi *et al.*[2] and Hill *et al.*[3], all of whom also observed the impact of the type of site and the type of tooth in periodontal measurements. Corraini *et al.*[17] likewise reported that the site influenced the reproducibility of the method, reporting a better reproducibility of the direct method on free surfaces.

Finally, it is necessary to look with more attention at the process of examiner reproducibility. Among the three examiners involved, two were responsible for assessing the VPI, GBI, presence of calculus, BOP, PPD and CAL_D. They were calibrated for PPD and CAL_D and achieved good intra- and inter-examiner ICC values. The third examiner only performed PPD and GR evaluations, and those measurements were used to generate the CAL_I values. This examiner was intracalibrated for PPD and GR – also achieving good ICC values – and was also intercalibrated for PPD against one of the first examiners (P.D.M.A.). This strategy of reproducibility was carried out because if the same examiner had assessed PPD, CAL_D and GR at the same time, the examiner probably would have been influenced by memory bias. Another factor influencing this issue could be the same examiner assessing PPD and CAL_D at one examination and assessing PPD and GR at another examination. However, this may also cause some bias because the clinical conditions can be different at the second examination. The possibility of bias caused by the fact that more than one examiner was involved in the examinations can be considered a limitation of the present study. However, it is believed that it might have a lower impact if compared with the possibility of data memory during consecutive examinations performed by a single examiner. Besides that, the ICC values obtained before and during the study, even without excluding the discussed bias, suggests that high intra- and inter reproducibility of examiners reduces measurement bias.

The results of the present investigation demonstrate the impact of the indirect method of CAL measurement on overestimating periodontal destruction. This finding is a relevant concern, especially in daily practice, because the sites or tooth are considered the units of analysis and the presence of errors in the probing measures can have an impact on decision making, such as the choice of one treatment or another, or the need for retreatment. Thus, considering the findings, both in respect to the choice of the best method for measuring the extent of clinical attachment loss as well as the need to minimise inherent errors, we suggest that the use of direct examination is preferable to the indirect method as an appropriate way to decrease measurement bias.

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None to declare.

Conflicts of Interest

The authors declare no conflict of interest associated with this study.

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REFERENCES

1. Glavind L, Löe H. Errors in the clinical assessment of periodontal destruction. *J Periodontal Res* 1967 2: 180–184.
2. Grossi SG, Dunford RG, Ho A *et al.* Sources of error for periodontal probing measurements. *J Periodontal Res* 1996 31: 330–336.
3. Hill EG, Slate EH, Wiegand RE *et al.* Study design for calibration of clinical examiners measuring periodontal parameters. *J Periodontol* 2006 77: 1129–1141.
4. Kingman A, Löe H, Anerud A *et al.* Errors in measuring parameters associated with periodontal health and disease. *J Periodontol* 1991 62: 477–486.
5. Michalowicz BS, Hodges JS, Pihlstrom BL. Is change in probing depth a reliable predictor of change in clinical attachment loss? *J Am Dent Assoc* 2013 144: 171–178.
6. Atassi F, Newman HN, Bulman JS. Probe tine diameter and probing depth. *J Clin Periodontol* 1992 19: 301–304.
7. Holtfreter B, Alte D, Schwahn C *et al.* Effects of different manual periodontal probes on periodontal measurements. *J Clin Periodontol* 2012 39: 1032–1041.
8. Slate EH, Hill EG. Discovering factors influencing examiner agreement for periodontal measures. *Community Dent Oral Epidemiol* 2012 40(Suppl 1): 21–27.
9. Barendregt DS, Van der Velden U, Timmerman MF *et al.* Comparison of two automated periodontal probes and two probes with a conventional readout in periodontal maintenance patients. *J Clin Periodontol* 2006 33: 276–282.
10. Bulthuis HM, Barendregt DS, Timmerman MF *et al.* Probe penetration in relation to the connective tissue attachment level: influence of tine shape and probing force. *J Clin Periodontol* 1998 25: 417–423.
11. van der Velden U. Probing force and the relationship of the probe tip to the periodontal tissues. *J Clin Periodontol* 1979 6: 106–114.
12. Watts TL. Probing site configuration in patients with untreated periodontitis. A study of horizontal positional error. *J Clin Periodontol* 1989 16: 529–533.

13. Badersten A, Nilvéus R, Egelberg J. Reproducibility of probing attachment level measurements. *J Clin Periodontol* 1984 11: 475–485.

14. Armitage GC, Svanberg GK, Löe H. Microscopic evaluation of clinical measurements of connective tissue attachment levels. *J Clin Periodontol* 1977 4: 173–190.

15. Fowler C, Garrett S, Crigger M *et al.* Histologic probe position in treated and untreated human periodontal tissues. *J Clin Periodontol* 1982 9: 373–385.

16. Magnusson I, Listgarten MA. Histological evaluation of probing depth following periodontal treatment. *J Clin Periodontol* 1980 7: 26–31.

17. Corraini P, Baelum V, Lopez R. Reliability of direct and indirect clinical attachment level measurements. *J Clin Periodontol* 2013 40: 896–905.

18. Clerehugh V, Abdeia R, Hull PS. The effect of subgingival calculus on the validity of clinical probing measurements. *J Dent* 1996 24: 329–333.

19. Haas AN, Gaio EJ, Oppermann RV *et al.* Pattern and rate of progression of periodontal attachment loss in an urban population of South Brazil: a 5-years population-based prospective study. *J Clin Periodontol* 2012 39: 1–9.

20. Kingman A, Albandar JM. Methodological aspects of epidemiological studies of periodontal diseases. *Periodontol* 2000 2002 (29): 11–30.

21. Susin C, Dalla Vecchia CF, Oppermann RV *et al.* Periodontal attachment loss in an urban population of Brazilian adults: effect of demographic, behavioral, and environmental risk indicators. *J Periodontol* 2004 75: 1033–1041.

22. Jeffcoat MK, Jeffcoat RL, Captain K. A periodontal probe with automated cemento–enamel junction detection-design and clinical trials. *IEEE Trans Biomed Eng* 1991 38: 330–333.

23. Araujo MW, Hovey KM, Benedek JR *et al.* Reproducibility of probing depth measurement using a constant-force electronic probe: analysis of inter- and intraexaminer variability. *J Periodontol* 2003 74: 1736–1740.

24. López R, Retamales C, Contreras C *et al.* Reliability of clinical attachment level recordings: effects on prevalence, extent, and severity estimates. *J Periodontol* 2003 74: 512–520.

25. Wang SF, Leknes KN, Zimmerman GJ *et al.* Intra - and inter-examiner reproducibility in constant force probing. *J Clin Periodontol* 1995 22: 918–922.

26. Page RC, Eke PI. Case definitions for use in population-based surveillance of periodontitis. *J Periodontol* 2007 78: 1387–1399.

27. Ainamo J, Bay I. Problems and proposals for recording gingivitis and plaque. *Int Dent J* 1975 25: 229–235.

28. Badersten A, Nilvéus R, Egelberg J. Effect of nonsurgical periodontal therapy. VII. Bleeding, suppuration and probing depth in sites with probing attachment loss. *J Clin Periodontol* 1985 12: 432–440.

29. Caton J, Greenstein G, Polson AM. Depth of periodontal probe penetration related to clinical and histologic signs of gingival inflammation. *J Periodontol* 1981 52: 626–629.

30. van der Velden U. Influence of periodontal health on probing depth and bleeding tendency. *J Clin Periodontol* 1980 7: 129–139.

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