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Validation of a dental image-analyzer tool to measure the radiographic defect angle of the intrabony defect in periodontitis patients

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Background and Objective: A report describing the software Dental Image Analyzer (DIA) was published in this journal in 2009. A new function – measurement of the periodontal intrabony defect angle – was added to the software in 2010. The purpose of this study was to investigate whether measurements of the radiographic intrabony defect angle using digital radiographs and the newly developed DIA tool were comparable with measurements obtained using the conventional protractor method.

Material and Methods: The baseline radiographic defect angle of intrabony defects was measured conventionally, using a protractor, in 60 selected teeth from 47 patients and then digitally using the newly developed DIA tool. The measurements were made independently by four experienced dentists. The radiographic defect angle of intrabony defects was measured after the three anatomical landmarks were identified, namely the cemento–enamel junction, the top of the crest and the bottom of the defect.

Results: Both methods showed a high interexaminer reliability for measurements of the radiographic defect angle of intrabony defects (intraclass correlation coefficient > 0.97). Moreover, both methods showed high reliability (intraclass correlation coefficient > 0.96). On the other hand, the new DIA tool, compared with the conventional method, exhibited high sensitivity (0.92) and high specificity (0.91) in selecting defects of $\geq 37°$ or $< 37°$. Analysis of the time taken for measurements revealed significant differences between the two methods, with the protractor method being more time consuming.

Conclusions: This study provided evidence for the lack of a significant difference between the conventional method and the DIA tool for radiographic measurement of intrabony defects. However, digital analysis was significantly faster.

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Periodontitis is an infection of the periodontium that results in the loss of connective tissue attachment and alveolar bone (1). It is a multifactorial disease and, in most cases, shows a chronic progression (2). Clinically, patients suffer from gradual loss of tooth attachment in the alveolar bone, which may lead to the formation of periodontal pockets, to gingival recession and eventually to tooth exfoliation. The rate of alveolar bone loss can be slow and continuous, or episodic, and bone loss can manifest as horizontal or angular (1).

Data on the prevalence of periodontal defects are scarce and are generally obtained from studies involving periodontal patients. Persson *et al*. (3) carried out a prevalence study of horizontal and vertical bone defects. They studied full-mouth, intra-oral, periapical radiographs of 416 patients. A total of 10,282 teeth were studied. They reported that 39.3% of patients had no vertical bone defects and 30.2% of patients had 3-mm vertical defects. Papapanou *et al*. (4) reported angular defects in 8% of the teeth they examined. In a recently published study (5), vertical bone defects represented 7.8% of periodontal bone defects.

Peri-apical radiographs are used to assess interproximal bone crest levels and the remaining bone support. The extent of interproximal osseous destruction can be estimated by measuring the distance between the cemento–enamel junction (CEJ) and the alveolar bone crest for horizontal defects, and between the CEJ and the base of the defect for angular defects (1). Periodontal vertical bone defects represent a special therapeutic challenge. Additionally, there is no consistent evidence that they are associated with local progression of the disease. Nevertheless, some studies (6,7) identified deep probing depth and reduced alveolar bone levels as local risk factors for further periodontal tissue loss. More recently, Muzzi *et al*. (8) concluded that the infrabony component of the defect and the amount of residual bone may be good prognostic factors for predicting tooth loss.

A correlation between radiographic changes in alveolar bone level (bone fill) occurring in intrabony defects after periodontal access flap surgery and the corresponding pretreatment defect angles was described in 1989 by Steffensen and Weber (9); they stated that a greater potential for bone filling was found in defects with small angles (0–45°) than in those with wide angles (45–90°). Tonetti *et al*. (10) showed that, for guided tissue regeneration, the wider the radiographic defect angle, the lower the regenerated probing attachment level in intrabony defects. Tsitoura *et al*. (11) have also shown a significant association between the baseline radiographic defect angle and clinical attachment level gain, 1 year after regenerative periodontal surgery with enamel matrix derivative. Thus, radiographs are an essential adjunct to clinical examination for formulating periodontal diagnoses and prognoses and for evaluating treatment outcomes (12).

With the recent advent of digital radiology, increasing numbers of professionals are adopting this technology. This new technology offers many advantages over conventional radiography. It eliminates the need for film and for film development, and the patient is exposed to lower levels of radiation. The image generated is available immediately on a computer screen and can be digitally manipulated to enhance viewing – for example, the image could be enlarged to focus on specific regions. In addition, digital tools are available to record electronic measurements and to cut, paste and color the image. The images can be easily saved on and retrieved from a hard disk or a removable storage medium, or the images can be transferred electronically to third-party carriers (13–15).

Informatics in medicine has evolved at an equal rate and consequently software programs have been designed to evaluate and quantify radiographic images, with applications in diagnosis and treatment in almost every area of dentistry, particularly in periodontology and implantology. In this context, the Institute of Electronics and Telematics Engineering of Aveiro (IEETA, University of Aveiro, Portugal), in partnership with the INFOBIOMED consortium (http://www.infobiomed.org), has developed a new dental image analyzer (DIA) tool (http://www.ieeta.pt/dia/) that is mostly applicable to periodontology and allows measurements to be made of radiographic parameters. Some functions of this new computer tool have already been scientifically validated (16). However, the program has been improved and recently a new quantification function for angular bone defects has been introduced.

The purpose of the present study was to test whether the use of this newly developed DIA tool yielded radiographic defect-angle measurements of the intrabony periodontal defect that are comparable with those obtained using the conventional method.

Material and methods

Image acquisition

Among patients receiving periodontal treatment at the Periodontology Department of the Faculty of Dental Medicine of the University of Oporto (Portugal), 70 individuals who presented with at least one visible angular bone defect on panoramic radiography were selected. All gave their informed consent to participate in this study, which complied with the recommendations made in the Helsinki Declaration for the protection of human subjects. The study was approved by the Ethics Committee of the faculty. Of 94 digital peri-apical radiographs were obtained using the long cone paralleling technique: a size one digital sensor Kodak RVG5100® (Kodak, Rochester, NY, USA) was positioned intra-orally with the aid of a plastic film holder (Dentsply XCP-DS®; Dentsply, Elgin, IL, USA) attached to a metal arm with a cone-guiding ring.

The inclusion criteria for the images selected for this study were the presence of essential anatomical points (11) (Fig. 1), namely: A (the CEJ of the tooth involved in the intrabony defect; if restorations were present, the apical margin of the restoration replaced the CEJ as a fixed reference point), B [the most coronal position of the alveolar bone crest of the intrabony defect

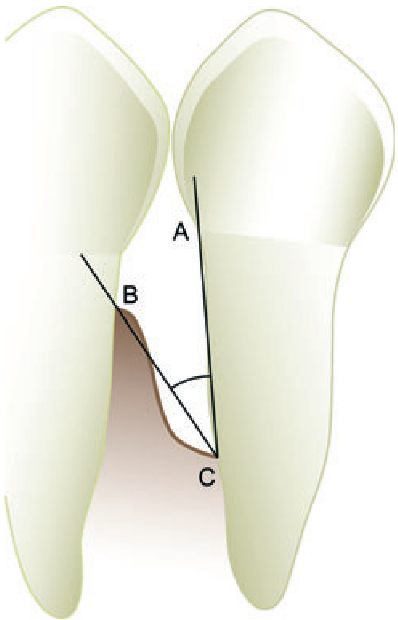

Fig. 1. Anatomical points and angle of the radiographic defect. A: the cemento–enamel junction (CEJ) of the tooth involved in the intrabony defect. If restorations were present, the apical margin of the restoration replaced the CEJ as a fixed reference point. B: the most coronal position of the alveolar bone crest of the intrabony defect where it touched the adjacent tooth root surface (the top of the crest). C: the most apical extension of the intrabony defect, where the periodontal ligament space still retained its normal width before treatment (the bottom of the defect).

where it touched the adjacent tooth root surface (the top of the crest)] and C [the most apical extension of the intrabony defect, where the periodontal ligament space still retained its normal width before treatment (the bottom of the defect)].

The angle of the radiographic defect was defined by the two lines that represent the root surface of the tooth involved and the surface of the bone defect (9–11). Image parameters, such as contrast and sharpness, were not taken into account.

Of the 94 peri-apical radiographs obtained, only 75 fulfilled all the inclusion criteria. Among those, 60 images of 47 patients were randomly selected for this study, with the aid of a computer program. The remaining 15 images were used to train, standardize and calibrate the four examiners from two different academic institutions. Examiner standardization required clear comprehension and appropriate application of the chosen criteria (17). A calibration exercise was carried out to obtain acceptable intra-examiner and interexaminer reproducibility, with reference to measurements made by a very experienced external examiner who represented the gold standard. Interexaminer agreement was evaluated as the standard error of the mean difference of the measurements performed by each of the four examiners and those performed by the gold-standard examiner. These were $< 1°$. Ninety per cent of the examiner's measurements were within a range of $\pm 3°$ relative to the values obtained by the gold-standard examiner.

The bone defect angle, observed on radiographs, was evaluated conventionally with a protractor from digital radiographs printed on photographic paper. The periodontal bone defect angle was also measured digitally using the same digital radiographs and the DIA tool constructed by Coelho *et al.* (http://www.ieeta.pt/dia/). All examiners started with conventional measurements. To avoid recognizing the radiographs when performing digital measurements, the conventional and the digital analyses were separated by an intervening period of at least 1 wk.

Conventional assessments

The 60 images (9.0 cm × 6.5 cm) were printed on high-quality photographic paper (Xerox® Colotech Silkcoated; Xerox, Norwalk, CT, USA) using a laser printer (Xerox® Phaser 7760; Xerox). The conventional measurements were made independently by each examiner, in a random order. A 1° gradation protractor (Rotring® S0237630; Rotring, Hamburg, Germany) was used. In the current study, the points corresponding to the three landmarks were marked in each image, as already described. All results were written on preprinted forms by the supervisor (author R.P.M.) during the measurements. Simultaneously, the duration of measurements for each image, for each examiner, was registered. Before statistical analysis, the recorded results were entered into a spreadsheet and checked for mistakes.

DIA tool measurements

The same 60 radiographic images used for conventional measurements were imported into the DIA software installed on a laptop (Sony VAIO® VGN-FZ21M; Sony, Tokyo, Japan) and displayed on a monitor with a resolution of 1280 × 800 pixels. The same four examiners participated in the digital measurements of radiographic angles. To determine the value of the angle, each professional marked the three reference points on each radiograph and the computer program automatically estimated the value of the angle (Fig. 2). As in the conventional method, the time taken for measurement was noted on a spreadsheet by the supervisor (author R.P.M.).

Data analysis

Statistical analysis was performed using SPSS version 18.0 (SPSS, Chicago, IL, USA). The interexaminer reliability for angular bone defect values per site, for both methods, was analyzed using the average intraclass correlation coefficient. This coefficient was calculated for pairwise combinations of all four examiners (paired observations). To compare the two methods, the mean differences per site were analyzed using the Wilcoxon test, and *p*-values of < 0.050 were considered significant. To examine intermethod reliability, site means of the angular bone-defect values were used to analyze the intraclass correlation coefficient. Because some studies (11,18,19) have designated 37° as the value above which the defect angle is classified as wide, data obtained using the two methods were classified into two categories: $< 37°$ and $\geq 37°$. With these two groups, we calculated the sensitivity and specificity of the DIA tool relative to conventional assessments.

Results

Of the 60 teeth with angular bone defects, selected from 47 patients (27 women) with periodontitis, ranging

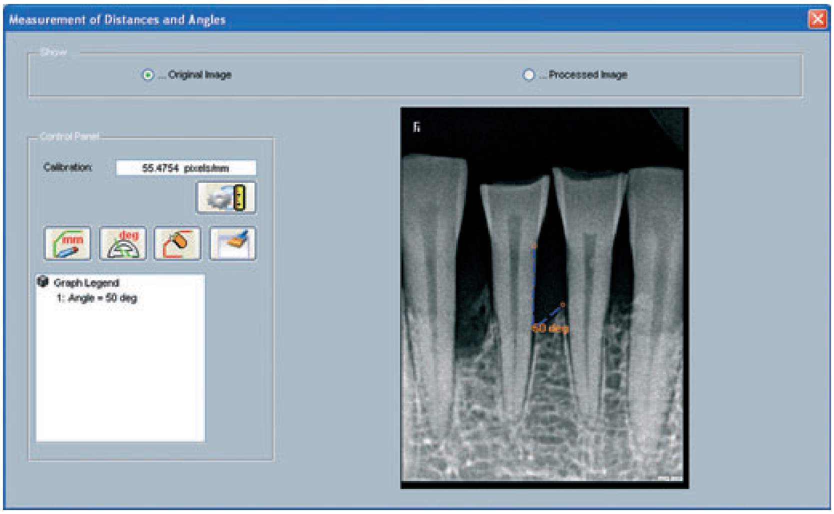

Fig. 2. Screen shot of the dental image analyzer (DIA) program. The intrabony defect angle of tooth 41 was measured.

from 20 to 69 years of age (mean age ± standard deviation = 46.5 ± 12.4 years), 27 were molars and 33 were not molars. The mean ± standard deviation of the angular bone-defect values, for all examiners, measured using conventional and digital methods, were 47.32 ±12.64° and 47.58 ±12.89°, respectively.

Interexaminer reliability

The intraclass correlation coefficients of conventional assessments for pairwise combinations of all four examiners (paired observations) ranged from 0.988 to 0.991 with a 95% confidence interval (CI) of 0.980–0.995 (Table 1). These intraclass correlation coefficients were significant. The same intraclass correlation coefficients of digital assessments for pairwise combinations of all four examiners (paired observations) ranged from 0.983 to 0.987 with a 95% CI of 0.972–0.992 (Table 2). These intraclass correlation coefficients were also significant.

Conventional assessment vs. DIA assessment

Comparison of defect angle values assessed using conventional and digital methods revealed no statistically significant differences ($p > 0.050$) (Table 3). Thus, measurements of the angle obtained using the digital method were similar to those obtained using the conventional method.

To determine intermethod reliability, we compared the results obtained for both methods by each examiner and the average of all examiners, with the intraclass correlation coefficient (Table 4). The intraclass correlation coefficient was > 0.75, which indicated excellent agreement between the results obtained by each examiner. The intraclass correlation coefficient ranged from 0.981 (95% CI: 0.969–0.989) for examiner A to 0.991 (95% CI: 0.985–0.995) for the global average analysis. These intraclass correlation coefficients were also significant.

The analysis of sensitivity and specificity after the classification of angle values into two categories (< 37° and

Table 1. Intraclass correlation coefficients of conventional assessments for pairwise combinations of all four examiners

	Conventional method		
Examiner	B	C	D
A	0.991 (95% CI: 0.986–0.995)	0.989 (95% CI: 0.981–0.993)	0.988 (95% CI: 0.980–0.990)
B		0.989 (95% CI: 0.981–0.993)	0.988 (95% CI: 0.980–0.993)
C			0.989 (95% CI: 0.981–0.993)

CI, confidence interval.

Table 2. Intraclass correlation coefficients of digital assessments for pairwise combinations of all four examiners

	Digital method		
Examiner	B	C	D
A	0.985 (95% CI: 0.975–0.991)	0.987 (95% CI: 0.979–0.992)	0.983 (95% CI: 0.972–0.990)
B		0.986 (95% CI: 0.977–0.992)	0.985 (95% CI: 0.975–0.991)
C			0.987 (95% CI: 0.978–0.992)

CI, confidence interval.

Table 3. Comparison of angle values between the two methods using the Wilcoxon test

Examiner	Conventional method	Digital method	Significance *p*-value
A	47.23 (12.56)	47.83 (13.01)	0.075
B	47.58 (12.63)	47.65 (12.61)	0.683
C	47.37 (13.09)	47.63 (13.25)	0.329
D	47.08 (12.57)	47.22 (13.01)	0.845
Average	47.32 (12.66)	47.58 (12.90)	0.204

Values are expressed as mean (standard deviation).

Table 4. Intermethod reliability between the two methods for each examiner and for the global average analysis

Conventional method	Examiner	Digital method A	B	C	D	Average
	A	0.981 (95% CI: 0.969–0.989)				
	B		0.985 (95% CI: 0.975–0.991)			
	C			0.985 (95% CI: 0.975–0.991)		
	D				0.984 (95% CI: 0.974–0.991)	
	Average					0.991 (95% CI: 0.985–0.995)

CI, confidence interval.

Table 5. Sensitivity and specificity of the dental image analyzer tool relative to conventional assessments

	Conventional method			
Digital method	Angle $<$ 37° (n)	Angle ≥ 37° (n)	Sensitivity	Specificity
Angle < 37° (n)	12	4	0.923	0.915
Angle ≥ 37° (n)	1	43		

Table 6. Comparison between the measurement durations for conventional and digital assessments using the Wilcoxon test

Examiner	Conventional method	Digital method	Significance p-value
A	113.47 (47.71)	23.28 (10.20)	$<$ 0.001
B	43.10 (8.93)	22.50 (9.31)	$<$ 0.001
C	62.13 (18.12)	22.92 (9.91)	$<$ 0.001
D	68.15 (18.11)	22.88 (7.72)	$<$ 0.001
Average	71.71 (16.64)	22.90 (4.84)	$<$ 0.001

Values are expressed as mean (standard deviation), in seconds.

≥ 37°) yielded the results shown in Table 5. Angle measurements with the digital method exhibited a high sensitivity (0.923) and a high specificity (0,915), compared with the angle measurements obtained by the conventional method. From the 60 radiographic images analyzed using both methods, 12 had an angle of $<$ 37°, whereas 43 had an angle of ≥ 37°.

The time spent by each examiner on each measurement for the two radiographic methods was also analyzed using the Wilcoxon test (Table 6). Highly significant differences ($p <$ 0.001) were observed between the conventional and the digital methods for each examiner, and for the global average values. Analysis of the values indicated that the time required to measure the angle using the digital method was much shorter than that required for the conventional method.

Discussion

In this study, radiographic images were acquired using a digital sensor. These images were analyzed either digitally using the DIA program or conventionally, on paper. We consciously chose this path. Alternatively, we could have tried to register the same angular defect with a radiographic film and with a digital sensor using individual film holders. However, we believe that this option would increase the error and compromise the results. It is also noteworthy that the paper images were printed with the same dimensions as those viewed on a computer screen. This allowed us to eliminate the difficulty of identifying landmarks on radiographic film. In addition, we reduced the financial and environmental impacts of this study as no individualized film holder was necessary and no double RX exposure was needed.

The intraclass correlation coefficient has been considered appropriate for the evaluation of both consistency and conformity studies because it is capable of estimating the proportion of the total variation caused by the variability between independent units of analysis. In the present study, the interexaminer reliability of both methods was excellent ($>$ 0.983), according to the intraclass correlation coefficient classification of Fleiss. This intraclass correlation coefficient value reflects high agreement between examiners for the same method. Fleiss suggested that scores of $<$ 0.4 represent poor reliability, scores of 0.4–0.75 represent fair to good reliability and scores of > 0.75 represent excellent reliability (20). Moreover, the intermethod reliability was excellent, as shown by the results in Table 4. Intraclass correlation coefficient values of > 0.981 reflect high agreement between methods.

In the sensitivity and specificity analyses, we chose a cut-off value of 37°, as previously explained. We concluded that the radiographic angle measurement obtained using the digital method, compared with the conventional method, has high sensitivity and specificity. With these sensitivity and specificity values close to 1, we can conclude that both methods are nearly coincident in the classification of angles.

In conclusion, no significant differences were observed between the radiographic angle measurements of a periodontal bone defect, using digital radiographs viewed on a monitor with the DIA tool and the conventional method of measurement using a protractor. However, given the widespread use of digital procedures, the DIA tool is preferred because this program saves the data directly into a database, enabling the (re)evaluation of Rx images in different computers. According to our study, the quantification of angular periodontal bone defects is substantially faster using the computer application. This is therefore a considerable advantage of the software.

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