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Validation of a dental image analyzer tool to measure alveolar bone loss in periodontitis patients

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Background and Objective: Radiographs are an essential adjunct to the clinical examination for periodontal diagnoses. Over the past few years, digital radiographs have become available for use in clinical practice. Therefore, the present study investigated whether measuring alveolar bone loss, using digital radiographs with a newly constructed dental image analyzer tool was comparable to the conventional method, using intra-oral radiographs on film, a light box and a Schei ruler.

Material and Methods: Alveolar bone loss of the mesial and distal sites of 60 randomly selected teeth from 12 patients with periodontitis was measured using the conventional method, and then using the dental image analyzer tool, by five dentists. The conventional method scored bone loss in categories of 10% increments relative to the total root length, whereas the software dental image analyzer tool calculated bone loss in 0.1% increments relative to the total root length after crucial landmarks were identified.

Results: Both methods showed a high interobserver reliability for bone loss measurements in nonmolar and molar sites (intraclass correlation coefficient ≥ 0.88). Also, a high reliability between both methods was demonstrated (intraclass correlation coefficient nonmolar sites, 0.98; intraclass correlation coefficient molar sites, 0.95). In addition, the new dental image analyzer tool showed a high sensitivity (1.00) and a high specificity (0.91) in selecting teeth with $\geq 50\%$ or $< 50\%$ alveolar bone loss in comparison with the conventional method.

Conclusion: This study provides evidence that, if digital radiographs are available, the dental image analyzer tool can reliably replace the conventional method for measuring alveolar bone loss in periodontitis patients.

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Periodontitis is a chronic multifactorial infectious disease of the supporting tissues of the teeth (1). It is estimated that between 10 and 15% of adults from 21 to 50 years of age, and about 30% of subjects > 50 years old, have severe periodontitis (2,3). Clinically, patients suffer from gradual loss of tooth attachment in the alveolar bone, leading to periodontal pockets, receding gums, loose teeth and eventually tooth exfoliation. Radiographically, on dental X-ray images, loss of supporting alveolar bone is visible around the roots of the teeth. Thus, radiographs are an essential adjunct to the clinical examination for formulating periodontal diagnoses and prognoses and for evaluating treatment outcomes (4). Alveolar bone loss is an accumulative measure of the disease suffered in a lifetime and is a very important periodontal disease variable (5). Alveolar bone measurements on X-ray images have been used by many research groups to characterize the extent and severity of periodontal disease (6,7).

Conventionally, intra-oral photographs on radiographic film are used to detect alveolar bone loss associated with periodontal disease. Assessments of alveolar bone loss are performed by 'hand', often using a Schei ruler, with or without magnification (8). Over the past few years, systems that can generate digital radiographic images without the need for radiograph film have become available for use in clinical practice and are gaining in popularity among dental practitioners and researchers (9). A few studies have examined the use of digital radiography in evaluating crestal alveolar bone loss. However, these studies were performed *in vitro* and were not compared with the conventional assessment of alveolar bone loss. Therefore, within the INFOBIOMED consortium (http://www.infobiomed.org), a dental image analyzer tool has been constructed (http://www.ieeta.pt/dia/) to perform digital measures of alveolar bone loss in periodontitis patients, mainly for research purposes. A full data set per patient on the extent and severity of accumulated alveolar bone loss as a result of periodontitis is an important parameter for describing the phenotype of each patient.

The purpose of the present study was to test whether the use of a newly constructed dental image analyzer tool gives comparable results of alveolar bone loss measurements compared with the conventional method of measuring alveolar bone loss. Interexaminer variations for both methods are reported.

Material and methods

From 91 periodontitis patients, included in a study by Bizzarro *et al.* (10), 12 patients with at least 24 teeth and a full set of dental radiographs (16 peri-apical radiographs), were randomly selected by a computer program. From these patients, five teeth per patient were selected at random on 40 peri-apical radiographs. For the radiographs a long cone paralleling technique was used; a full-size digital sensor (Sirona, Bensheim, Germany) for the post canine region, or a universal digital sensor (Sirona) for the front teeth was positioned intra-orally with the aid of a plastic film holder (Sirona) attached to a metal arm with a cone-guiding ring. Radiographs had to meet one criterion: the landmarks used (the cemento–enamel junction, the alveolar crest and the apex) had to be visible. Criteria such as contrast, sharpness, etc., were not taken into account. From the selected teeth, the bone height at mesial and distal sites was measured as a percentage of root length in two different ways. The bone height was assessed in a conventional way, using digital radiographs printed on film, analyzing them on a light box with a Schei ruler (8). The bone height was measured digitally, using digital radiographs and a dental image analyser tool constructed by Coelho *et al.* (http://www.ieeta.pt/dia/). All examiners started with the conventional measurements. To prevent recognition of some X-rays when measuring using the dental image analyzer tool there was an intervening period of at least 1 wk between conventional measurements using radiographs and measurements made using the dental image analyzer tool.

Conventional assessments

The percentage of bone loss was determined by five experienced dentists from the Department of Periodontology, Academic Centre for Dentistry Amsterdam (ACTA). The bone loss determinations were carried out independently and in random order per dentist on 40 digital radiographs printed on film (Agfa DRYSTAR 4500; Agfa, Mortsel, Belgium) via a flat standard view box (Just Normlicht, Weilheim/Teck, Germany) using a Schei ruler. The Schei ruler (Fig. 1) used was a plastic transparent ruler with a 1-mm-thick marking at its margins and 10 equidistant lines radiating from a center point, each representing 10% bone loss. According to Schei *et al.*, the 1-mm-thick marking represents the distance between the cemento–enamel junction and the alveolar crest in 'normal' humans with no bone loss (8). This technique results in the determination of bone loss as a percentage of the 'original' bone level, starting 1 mm below the cemento–enamel junction, irrespective of the length of the root and its length on the radiograph and irrespective of the direction of the X-ray beams. In the current study, bone loss was determined as the percentage of root length. Therefore, the ruler was placed on the tooth in question with the 1-mm-thick marking coronal at the tooth radiographic cemento–enamel junction and perpendicular at the longitudinal axis of the root. Then, the ruler was moved until the last radius covered the radiographic apex. In the case of lower molar teeth with mesial and distal roots, the apex of the root at the site to be measured was used. In the case of the upper molar teeth, the same root as for the lower molar teeth was used, in fact ignoring the palatal root. The 'actual' amount of bone loss as a percentage of root length was determined by identifying the position of the alveolar crest relative to the ruler's markings (Fig. 2A,B). The level of the bone crest was defined as the point along the root where an intact lamina was observed. The actual amounts of bone loss as a percentage of root length could fall into one of 10 categories (bone loss index, Table 1).

Where no interproximal fillings were present, the cemento–enamel junction could be localized in the vast majority of cases with certainty. In some cases, the cemento–enamel junction was obscured by interproximal fillings. In these cases the cervical margin of the fillings was chosen as a surrogate cemento–enamel junction. All measurements were written on preprinted forms by the supervisor (author W. T.)

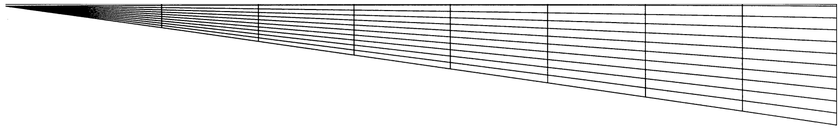
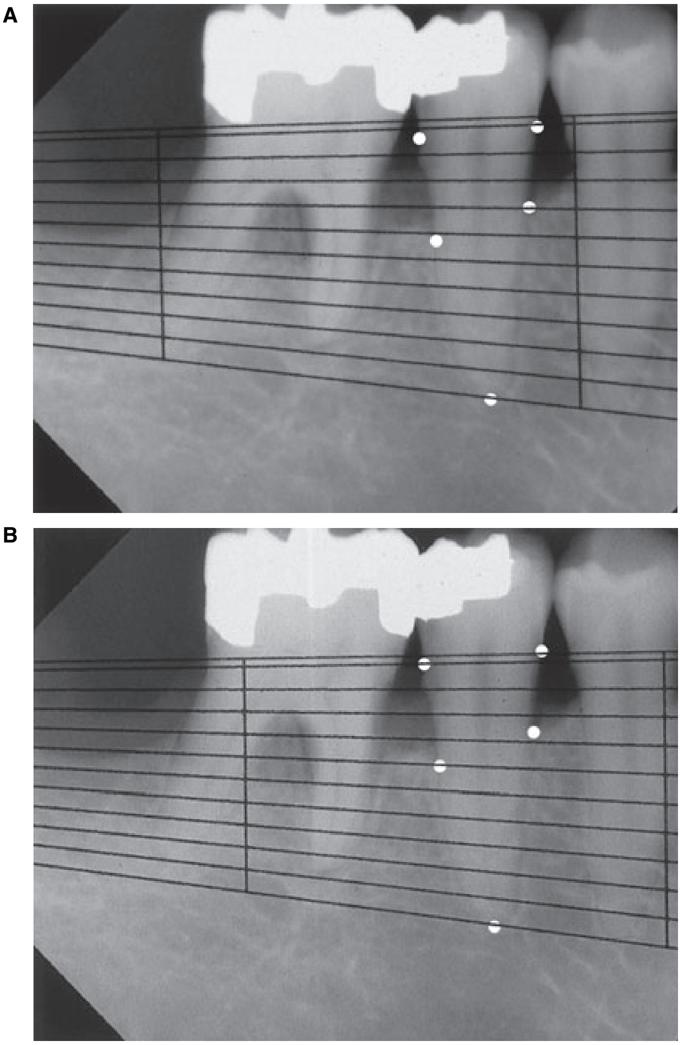


Fig. 1. The Schei ruler (8).



C

Tooth	Observer 1	
	Alveolar bone loss (BLI)	
	Mesial	Distal
45	4	5

Fig. 2. Bone loss measurement at mesial (A) and distal (B) sites of tooth 45 made using the Schei ruler. (C) An example of data entry into a spreadsheet. Mesial site, bone loss index 4 (30 to < 40% alveolar bone loss, Table 1). Distal site, bone loss index 5 (40 to < 50% alveolar bone loss).

Table 1. Bone loss in percentage of total root length and corresponding bone loss index

Bone loss (percentage of total root length)	Bone loss index
< 10	1
10 to < 20	2
20 to < 30	3
30 to < 40	4
40 to < 50	5
50 to < 60	6
60 to < 70	7
70 to < 80	8
80 to < 90	9
≥ 90	10

during the measurements. At the same time, the duration of measurements for each patient per observer was also noted. After each 30 min period of taking measurements, the observer took a break for at least 15 min. Afterwards, the written results were entered into a spreadsheet (Fig. 2C). Before statistical analysis, the entered data were checked for mistakes.

Dental image analyser tool measurements

Within the INFOBIOMED consortium (http://www.infobiomed.org), a dental image analyser tool (DIA 1.6-study, http://www.ieeta.pt/dia/) has been constructed to perform digital measures of alveolar bone loss in periodontitis patients. The 40 digital radiographs used for the conventional assessments were imported into the dental image analyzer tool and viewed using a plug and play monitor (Dell, Dublin, Ireland; resolution 1024 by 768 pixels) on an Intel® 82865G Graphics Controller. To determine the percentage of bone loss, the same five experienced dentists, who also performed the conventional assessments, participated. These dental image analyzer tool measurements per dentist were again made in random order and performed at least 1 wk later than the conventional assessments. The dentists marked the following using the program DIA 1.6-study: (i) the cemento–enamel junction; (ii) the position of the alveolar crest along the root; and (iii) the radiographic apex (Fig. 3). To determine the location of the cemento–enamel junction, the position of the alveolar crest and the location of the apex (the same criteria as described above under 'Conventional assessments') were used. Immediately, the dental image analyzer tool calculated the bone loss in percentage of total root length at the mesial and distal sites of the selected tooth and saved the results directly into a spreadsheet. Again, as with the conventional assessments, the duration of the measurements for each patient per observer were noted on preprinted forms by a supervisor (author W. T.). After each 30-min period of taking measurements, the observer took a break for at least 15 min.

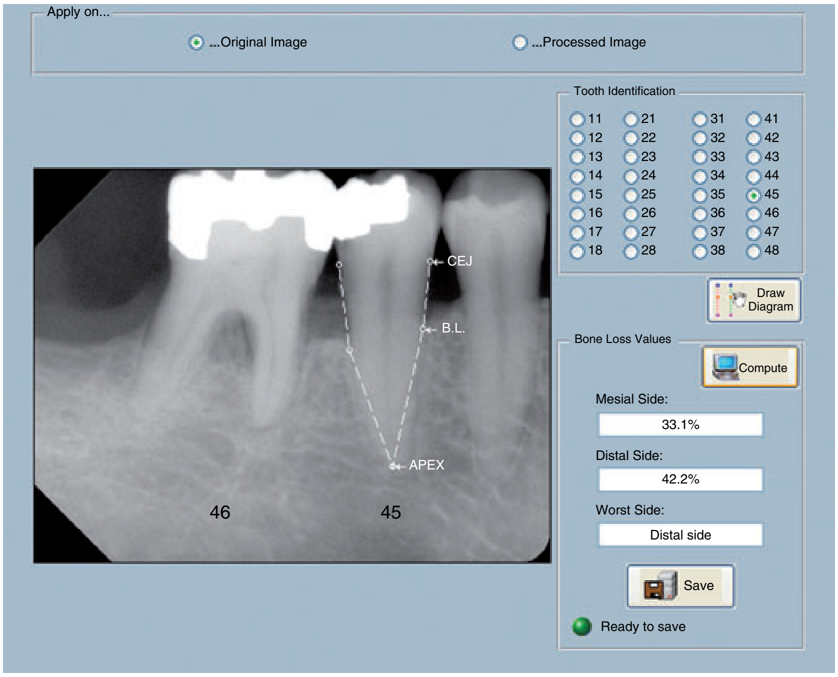


Fig. 3. Screen shot of the dental image analyzer tool program. Alveolar bone loss is measured of tooth 45 as percentage of total root length. Location of the landmarks: cemento–enamel junction (CEJ), alveolar bone level (B.L.) and the apex (APEX). The mesial site showed 33.1% alveolar bone loss (bone loss index 4) and the distal site showed 42.2% alveolar bone loss (bone loss index 5).

Data analysis

Statistical analysis of data was performed using the SPSS package version 11.0 (SPSS, Chicago, IL, USA). The interexaminer reliability for the 'actual' amount of alveolar bone loss per site for both methods was analyzed using the average intraclass correlation coefficient. Furthermore, intraclass correlation coefficients were calculated for all combinations of two observers (paired observations). It has been suggested by Fleiss that a score below 0.4 may be taken to represent poor reliability, a score above 0.75 may be taken to represent excellent reliability and scores between 0.4 and 0.75 represent fair to good reliability (11). To allow comparison of the results obtained with both methods, all absolute percentage values obtained using the dental image analyzer tool measurements were transformed into bone loss index values (Table 1). For each method, alveolar bone loss values were averaged for the five examiners per site. For intermethod reliability, site means of the 'actual' amount of alveolar bone loss were used for the analysis of the intraclass correlation coefficient. To compare both methods, mean differences per site were analyzed by use of the Wilcoxon test and *p*-values of < 0.05 were accepted as being statistically significant. In addition, to compare both methods, the site means differences were analyzed graphically, a technique described by Bland & Altman (12).

Because ≥ 50% alveolar bone loss, relative to total root length, is classified as severe periodontitis (13), data obtained from both methods were also transformed into two categories: < 50% alveolar bone loss (given a value of 0) and ≥ 50% alveolar bone loss (given a value of 1). The interexaminer reliability for these categories of alveolar bone loss per tooth for both methods was analyzed using the intraclass correlation coefficient (a tooth was categorized with ≥ 50% alveolar bone loss if one or both sites had ≥ 50% alveolar bone loss). In addition, sensitivity and specificity of the dental image analyzer tool in comparison with the conventional assessments was calculated for each tooth.

Results

Background characteristics of material used

Sixty teeth (37 nonmolar teeth and 23 molar teeth) were selected on 40 periapical radiographs obtained from a total of 12 patients with periodontitis. All selected teeth showed, after analysis using the conventional assessment and the dental image analyzer tool, alveolar bone loss at both mesial and distal sites. Detailed below are background information on bone loss characteristics (averaged for all observers) of the teeth used in this comparative study.

Conventional method — The mean bone loss index (Table 1) per site for all teeth, measured using the conventional method, was 4.14 ± 1.49 (range: 1.60–7.60). Corresponding values per site for nonmolar and molar teeth were 3.95 ± 1.59 (range: 1.60–7.60) and 4.44 ± 1.28 (range: 2.00–7.40), respectively. A mean bone loss index of ≥ 6 (≥ 50% bone loss) at one or both sites was found in 7 (19%) of the nonmolar teeth and in 7 (30%) of the molar teeth.

Dental image analyzer tool — The mean bone loss index per site measured using the dental image analyzer tool was, for all teeth, 4.35 ± 1.43 (range: 1.20–8.00). Corresponding values per site for nonmolar and molar teeth were 4.13 ± 1.51 (range: 1.20–8.00) and 4.70 ± 1.24 (range: 2.80–7.80), respectively. A mean alveolar bone loss of ≥ 50% at one or both sites was found in 10 (27%) of the nonmolar teeth and in 8 (35%) of the molar teeth.

Interexaminer reliability for 'absolute' measurements

In Table 2 it can be seen that the intraclass correlation coefficient of the conventional assessments, performed by five different examiners, for all sites

Table 2. Interexaminer reliability for 'absolute' values of 'hand' measurements, dental image analyzer tool measurements and 'transformed' dental image analyzer tool measurements

Sites	*n* sites	ICC 'conventional'	ICC DIA tool	
			'raw' DIA	'transformed' DIA[a]
All sites	120	0.94* (95% CI: 0.92–0.96)	0.93* (95% CI: 0.90–0.95)	0.93* (95% CI: 0.90–0.95)
Nonmolar sites	74	0.96* (95% CI: 0.95–0.98)	0.95* (95% CI: 0.92–0.97)	0.94* (95% CI: 0.91–0.96)
Molar sites	46	0.88* (95% CI: 0.81–0.93)	0.89* (95% CI: 0.82–0.94)	0.88* (95% CI: 0.81–0.93)

*$p < 0.001$.
[a]Values of the dental image analyzer tool measurements were transformed into bone loss index (Table 1) values.
Results are expressed as average intraclass correlation coefficient (ICC) with 95% confidence interval (CI) between all examiners for all sites, nonmolar sites and molar sites.
DIA, dental image analyzer.

was 0.94 (95% confidence interval: 0.92–0.96); the intraclass correlation coefficient was significant. In addition, the intraclass correlation coefficient of the paired observations ranged from 0.76 to 0.93 (data of paired observations not shown). The intraclass correlation coefficient of the 'raw' dental image analyzer tool measurements for all sites was 0.93 with a 95% confidence interval of 0.90–0.95; this intraclass correlation coefficient was significant. The intraclass correlation coefficient of the paired observations ranged from 0.67 to 0.92 (data not shown). The intraclass correlation coefficients of the conventional and the dental image analyzer tool measurements for all sites were similar. Moreover, the results of the paired observations showed a very similar range. Table 2 shows that the intraclass correlation coefficient of the 'transformed' data of the dental image analyzer tool measurements for all sites was 0.93 (95% confidence interval: 0.90–0.95); this intraclass correlation coefficient was significant. In addition, the intraclass correlation coefficient of the paired observations ranged from 0.67 to 0.91. The intraclass correlation coefficient and the 95% confidence interval of the 'raw' data and the data obtained using the dental image analyzer tool 'transformed' into bone loss index values were identical for all sites. Furthermore, the ranges of intraclass correlation coefficients of the paired observations of both categories showed a high similarity.

Intraclass correlation coefficients were also calculated for nonmolar and molar sites. It was interesting to note that for all methods – conventional, and 'raw' and 'transformed' using the dental image analyzer tool – the intraclass correlation coefficient of the nonmolar sites was slightly higher than the intraclass correlation coefficient of the molar sites. In addition, the intraclass correlation coefficient ranges of paired observations for molar sites (conventional: 0.50–0.91; 'raw' dental image analyzer tool: 0.42–0.90; 'transformed' dental image analyzer tool: 0.38–0.89) clearly showed higher variation than the ranges for nonmolar sites (conventional: 0.86–0.94; 'raw' dental image analyzer tool: 0.77–0.96; and 'transformed' dental image analyzer tool: 0.77–0.95).

Interexaminer reliability for tooth determination with ≥ 50% bone loss

Table 3 shows the interexaminer reliability for tooth determination with ≥ 50% bone loss using both conventional and dental image analyzer tool measurements. The intraclass correlation coefficient of the conventional assessments for all sites was 0.93 (95% confidence interval: 0.90–0.96); the intraclass correlation coefficient was significant. The intraclass correlation coefficient of the paired observations ranged from 0.75 to 0.91. The intraclass correlation coefficient of the dental image analyzer tool measurement for all sites was 0.94 and was significant. The 95% confidence interval was 0.92–0.96 and the results of the paired observations ranged from 0.78 to 0.94. The intraclass correlation coefficient of the dental image analyzer tool for all sites was similar to the intraclass correlation coefficient of the conventional assessments.

All intraclass correlation coefficients were also calculated for nonmolar and molar sites. For both categories it was found that the intraclass correlation coefficients of conventional assessments were similar to these of the dental image analyzer tool measurements. Also, the range of the paired observations of the nonmolar (conventional: 0.82–1.00; dental image analyzer: 0.81–1.00) and molar (conventional: 0.56–0.95; dental image analyzer: 0.66–0.96) sites of both methods showed high similarity. It was interesting to note that the intraclass correlation coefficient of both methods increased for the nonmolar sites and decreased for the molar sites in comparison with the intraclass correlation coefficient for all sites. In addition, the

Table 3. Interexaminer reliability for bone loss values representing ≥ 50% of the total root length per tooth for 'hand' measurements and dental image analyzer tool measurements

Teeth	*n* teeth	ICC 'conventional'	ICC DIA
All teeth	60	0.93* (95% CI: 0.90–0.96)	0.94* (95% CI: 0.92–0.96)
Nonmolar teeth	37	0.96* (95% CI 0.94–0.98)	0.97* (95% CI: 0.94–0.98)
Molar teeth	23	0.88* (95% CI: 0.79–0.94)	0.91* (95% CI: 0.84–0.96)

*$p < 0.001$.
Results are expressed as average intraclass correlation coefficient (ICC) with 95% confidence interval (CI) between all examiners for all sites, nonmolar sites and molar sites.
DIA, dental image analyzer.

paired observations of the molar sites for both methods showed a higher variation than these of the nonmolar sites.

Conventional assessment vs. assessment using the dental image analyzer tool

Figure 4 shows mean bone loss differences between the conventional method and the dental image analyzer tool. The dental image analyzer tool measured, for all sites, significantly more bone loss compared with the conventional method (mean difference −0.21 ± 0.45). The intraclass correlation coefficient of the absolute measurements for all sites was 0.97 (95% confidence interval: 0.94–0.98); the intraclass correlation coefficient was significant. Again, for nonmolar and molar sites, mean bone loss differences (−0.18 ± 0.44 and −0.26 ± 0.47, respectively) and the intraclass correlation coefficient [0.98 (95% confidence interval: 0.96–0.99) and 0.95 (95% confidence interval: 0.88–0.98), respectively] were calculated. All differences were significant.

The results in Table 4 showed a sensitivity of 1.00 and a specificity of 0.91 of the dental image analyzer tool measurements in comparison with the conventional assessments in each tooth. The dental image analyzer tool measured 14 of 14 teeth to have ≥ 50% bone loss and 42 of 46 teeth to have < 50% bone loss compared with the conventional method.

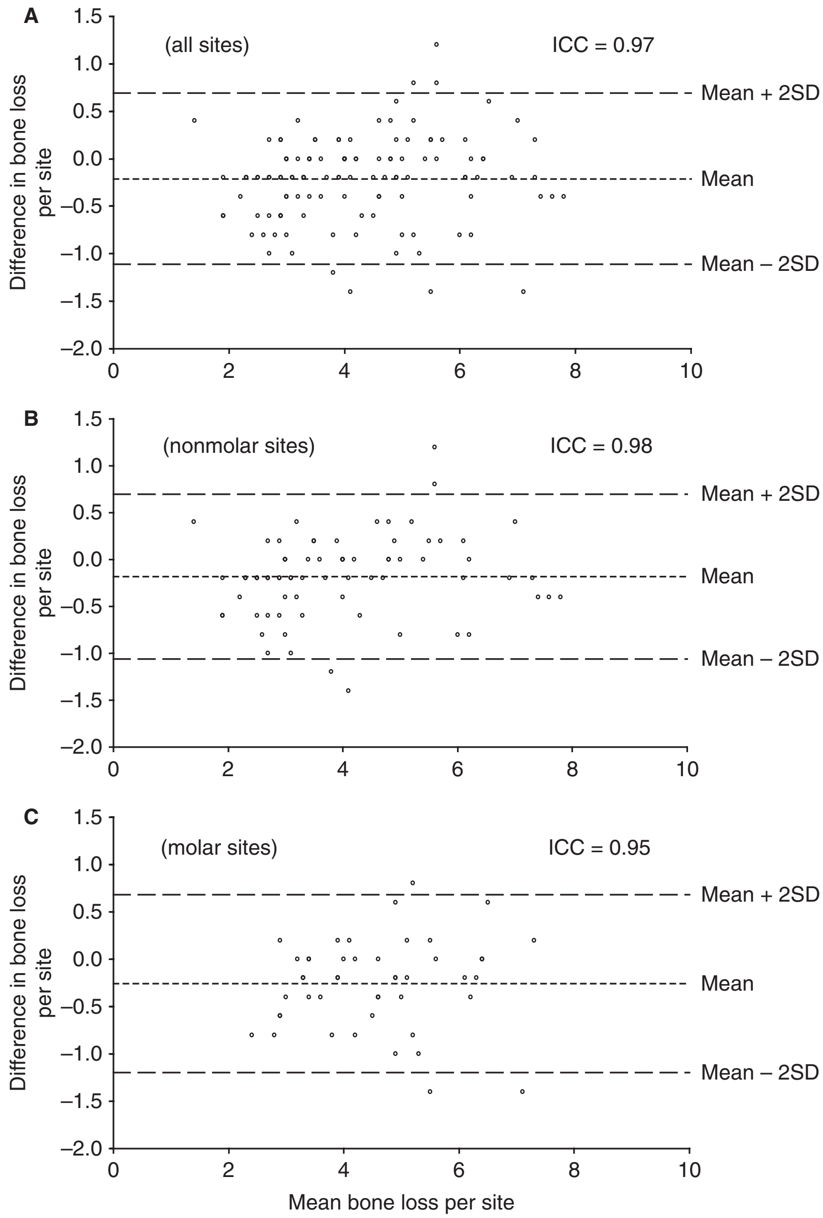


Fig. 4. Mean bone loss differences per site (*y*-axis: bone loss index) between the conventional method and dental image analyzer tool for (A) all teeth, (B) nonmolar teeth and (C) molar teeth are plotted against the mean bone loss per site (*x*-axis: bone loss index) for both methods. The intraclass correlation coefficient (ICC) is calculated for all categories. SD, standard deviation.

Table 4. Sensitivity and specificity of the dental image analyzer tool in comparison with the conventional assessments based on < 50% bone loss or ≥ 50% bone loss of total root length per tooth

	Conventional assessment (per tooth)[a]			
	≥ 50%	< 50%	Sensitivity	Specificity
DIA tool (per tooth)				
≥ 50%	14	4	1.00	0.91
< 50%	–	42		

[a]$n = 60$.
DIA, dental image analyzer.

Table 5. Measurement duration and mean duration differences for conventional assessments and those carried out using the dental image analyzer tool: results are expressed as min ± standard deviation

Sites	*n* sites	'Conventional'[a]	DIA tool[b]	Comparison 'conventional' minus the DIA tool	*p*-value
All sites	120	63.4 ± 15.6	66.4 ± 8.1	−3.0 ± 14.58	0.67

[a]Time measured did not include data entry into a spreadsheet.
[b]Time measured did include the automatic import of data into a spreadsheet.
DIA, dental image analyzer.

The results of the duration of the measurements showed no significant difference between the conventional method and the dental image analyzer tool (Table 5). However, the dental image analyzer tool imported the measured data directly into a spreadsheet, whereas the data of the conventional assessments was written on a preprinted form and was subsequently entered manually into a spreadsheet. It is interesting to note that the variation between the observers for the conventional and the dental image analyzer tool measurements, to measure the bone loss of the complete set of 120 sites, ranged from 46 to 85 min and from 55 to 72 min, respectively. It is noteworthy that all duration results did not include the duration of the pauses after each 30 min of measurements per observer.

Discussion

Intra-oral radiographs are an essential adjunct to the clinical examination for diagnosis, prognosis and treatment planning of subjects with periodontitis (4). Conventionally, radiographs on film have been used to measure alveolar bone loss. However, over the past few years, digital radiographs have been gaining in popularity among practitioners and researchers (9). In addition to clinical practice, radiographic analysis of alveolar bone levels to measure the extent and severity of periodontal destruction is widely used in periodontal research. The focus of the present investigation was to determine if measuring alveolar bone loss, using digital radiographs with a newly constructed dental image analyzer tool (http://www.ieeta.pt/dia/), has reproducibility similar to that of the conventional way of measuring, namely using intra-oral photographs on film, a light box and a Schei ruler.

All selected teeth were found, with both methods, to have alveolar bone loss at the mesial and distal sites. Both methods measured a mean alveolar bone loss per site for all teeth of between 40 and 50% of the total root length. Within the mean alveolar bone loss values, molar teeth showed, for both methods, slightly more alveolar bone loss than nonmolar teeth. Interestingly, the dental image analyzer tool always measured slightly more alveolar bone loss than the conventional method. One possible explanation for this could be an alteration of image density during the printing process, which could impair the visualization of the landmarks used (the cemento–enamel junction, the alveolar crest and the apex). Fuge *et al.* reported the inferiority of digitized images when compared with conventional radiographs for the determination of size 06 k-files in molar root canals, indicating that the image quality of digital images of radiographs was not good enough for this task (14). Therefore, we put the hypothesis forward that printing a digital image affects the quality.

Fleiss *et al.* showed that measurements of sites in the same mouth were positively correlated (15,16). In their study, several radiographs from the same mouth were used and this may have resulted in overstated statistical significance. However, all sites or teeth in this study were considered to be independent units of analysis because the main question was to analyze measurement reliability of each site or tooth instead of comparing measurements of sites within the same radiograph.

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. The dependence upon the degree of variability between observers has been considered a limitation of the intraclass correlation coefficient from a clinical point of view (17). As demonstrated in Tables 2 and 3, the interexaminer reliability of both methods for all categories (all sites, nonmolar sites and molar sites) was excellent, according to the intraclass correlation coefficient classification of Fleiss (11). As demonstrated, conversion of the dental image analyzer tool results into bone loss index values ('transformed' DIA), as used by the conventional assessments (Table 1), did not highlight any significant differences. Similar interexaminer reliability results were obtained by a comparable study in which the reliability of two methods (analog and digital) for measurement of alveolar bone level in children was determined (18). By contrast, several previous reports indicated substantial interexaminer variability in interpreting bone levels on conventional radiographs (19,20).

A possible explanation for this lack of consistency between several previous studies and our study in interexaminer reliability of bone loss measurements could be the use of different statistical techniques. A drawback of our study design was the lack of a counterbalanced design; each dentist made the conventional measurements first. This scheme may not control for potential confounding as a result of order or sequence effects associated with the method of measurement. However, a period of at least 1 wk was allowed to elapse between the different methods of measurement to prevent recognition of some X-rays by the observer during measuring with the dental image analyzer tool.

For both methods the intraclass correlation coefficients of the bone loss measurements for nonmolar sites were slightly higher than these of the molar sites and of all sites (Table 2). Therefore, bone loss measurements of nonmolar sites on peri-apical radiographs can be more accurately measured than these of molar sites. This suggestion is also confirmed by the findings if observers are paired: based on the range differences of intraclass correlation coefficients of the paired observations, more agreement was seen with measurements in the nonmolar sites than in the molar sites. A possible explanation for this could be the degree of increased difficulty in determining the landmarks (the cemento–enamel junction, the alveolar crest and the apex) for multirooted teeth. The landmarks in the molar region can be obscured as a result of overprojection of adjacent teeth and their roots, and of bony structures (the sinus, jugal bar, mandibular linea, etc.). Moreover, real differences in alveolar bone height between vestibular and lingual sites seem to be more pronounced and more difficult to interpret in the molar regions.

According to the excellent interexaminer reliability for both methods we considered the measurements per examiner per method as repeated measurements. This consideration allowed us to average the results per site per method as is recommended by Bland & Altman (12). Comparison of the two methods showed that in general the dental image analyzer tool always measured deeper than the conventional method. In addition, the mean bone loss differences of 95% of all observations for all sites ranged within ± 0.90 bone loss index (Fig. 4A). However, these differences are clinically acceptable because the severity classification per tooth based on ≥ 50% alveolar bone loss showed a perfect sensitivity and high specificity between the conventional assessments and the dental image analyzer tool (Table 4). This conclusion is also supported by the excellent intraclass correlation coefficient between the two methods for all categories.

In conclusion, we suggest that this study provides evidence that there is no substantial difference between measuring alveolar bone loss around teeth on digital radiographs on a monitor using the dental image analyzer tool and the conventional method of measuring using a Schei ruler, radiographs on film and a view box. However, in terms of time, accuracy and processing the measurement results, the dental image analyzer tool is preferred because this program saves the data directly into a database. Also, common advantages of digital radiography, for example the possibility for digital storage and (re)evaluation on different computers, pleat for the use of the dental image analyzer tool. Another advantage of the dental image analyzer tool is the possibility of processing an image optimally before measuring. In this study the digital radiographs were unprocessed. Therefore, further research should be carried out to investigate if image enhancement can improve the interexaminer and intermethod reliability. Another suggestion for future work is to include more parameters in the dental image analyzer tool program, for example, the possibility of quantifying angular bony defects, radiolucencies in furcation areas and peri-apical radiolucencies. These parameters give more information about the bony support of teeth in a research study.

Demo-version DIA Tool 1.799

Information about and a free demo-version of the dental image analyzer tool is available on http://www.ieeta.pt/dia/.

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