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THE CONSISTENCY AND RELIABILITY OF PERIODONTAL BONE LEVEL MEASUREMENTS USING DIGITAL SCANNING RADIOGRAPHIC IMAGE ANALYSIS- A PILOT STUDY

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The purpose of the present study was to evaluate the consistency and reliability of alveolar bone height measurement using digital scanning radiographic image analysis (DSRIA). A randomly selected (standardized paralleling technique) periapical radiographs of 20 molar teeth (10 maxillary molars and 10 mandibular molars) from 178 individuals with periodontitis were reporting or referred to the patient population of the dental clinics of the teaching hospital. Radiographic measurements were performed and read by two examiners, with a separation time of three weeks of different tooth groups and as established by double reading of 20 molar teeth in 10 individuals using the DSRIA. The calculating data of radiographic alveolar bone loss (RABL) measured and analyzed by the DSRIA for each molar group were compared based on the inter- and intra-examiners' data. The means and standard deviations were calculated to compare radiographs of the inter- and intra-examiners' groups. The reliability coefficients were computed to assess the consistency and reliability for each molar group. The results revealed that the intra- and inter-examiners' reliability coefficients ranged from 0.986 to 0.995 ($p<0.001$, significantly different from 0). An excellent reproducibility was indicated in maxillary molar, mandibular molar and of both arches, respectively. It was concluded that the standard periapical radiograph using the DSRIA has the potential to be a valuable and reliable method in measuring linear alveolar bone defects caused by periodontitis.

Key words: digital radiograph, alveolar bone defects measuring, reliability

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Initial periodontitis may be assessed by clinical probing of periodontal attachment and radiographic measuring of alveolar bone loss. Previous studies postulated, however, that the initial stage of the marginal periodontitis with small changes or crest bone loss is not accurately estimated by conventional radiography [1-3]. Therefore, periodical radiographic analysis for the quantity of alveolar bone loss is primarily indicated for periodontally involved subjects with the proximal surfaces and the interdental alveolar crest. Despite some limitations such as inability to accurately image the bone density (quality), to buccally and lingually locate the periodontal osseous defects, conventional radiography (CR) has remained the most frequently used sensor in clinical and epidemiological studies to assess radiographic alveolar bone level in relation to periodontal disease [4-7] A great number of studies [1,2, 8-11] demonstrated that the digital radiography is more sensitive than the conventional radiography (CR) for

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detection of small changes included quantity and quality, especially in the quality of alveolar bone loss. Its high accuracy and detailed diagnostic characteristics for the detection of subtle periodontal osseous change in bone height and density makes it successful in the confirmation of the presence of periodontal osseous defects or the progressive loss of alveolar bone [7,12]. In addition, previous studies also showed that the digital radiograph is more accurate than the conventional radiograph in image resolution and precision [13-15].

Limited information about consistency and reliability diverging on the radiographic method quantitatively measuring the alveolar bone levels by using digital scanning radiographic image analysis (DSRIA), is available. The purpose of present study was undertaken to evaluate the recording reliability and consistency of radiographic alveolar bone levels (RABL) in both the intra- and the inter-examiners' groups using a newly developed method, entitled "digital scanning radiographic image analysis (DSRIA)".

MATERIALS AND METHODS

Difference of heterogeneity

To evaluate the standard deviation from the radiographic images taken from a known length of ten metal wires with 20x and without magnification. The difference of heterogeneity between radiographs with 20x and without magnification was assessed by measuring the radiographic data. All radiographs with and without magnification were measured by five experienced operators. The difference of measured data following the reevaluation of ten pairs of radiographs with and without magnification was compared and analyzed using the square root of within class mean square test (Table 1).

Sample collection

Twenty molar teeth (10 maxillary molars and 10 mandibular molars) were randomly selected from a total of 178 individuals (96 males and 82 females), ranging in age from 24 to 75 years (mean age 43.1

Table 1. The difference in measuring radiographic data from the known length of 10 metal wires following repeated measurements with 20x (A) and without magnification (B)

Known Length	A		B		mean of	sd(A) / sd(B)	CV(A)	CV(B)
Wire(mm)	mean	sd	mean	sd	A-B	(%)	(%)	(%)
5	5.04	0.0487	5.32	0.0837	-0.29	58.25	0.97	1.57
6	6.06	0.0114	6.36	0.1517	-0.30	7.52	0.19	2.38
7	7.04	0.0360	7.18	0.4147	-0.14	8.67	0.51	5.78
8	8.02	0.0326	8.34	0.1140	-0.32	28.59	0.41	1.37
9	9.04	0.0224	9.24	0.1673	-0.21	13.36	0.25	1.81
10	10.04	0.0285	9.92	0.4494	0.12	6.34	0.28	4.53
11	11.04	0.0224	11.08	0.4494	-0.04	4.98	0.20	4.06
13	13.03	0.0185	13.24	0.2702	-0.19	6.85	0.14	2.04
14	14.04	0.0305	14.00	0.4183	0.04	7.30	0.22	2.99
15	15.06	0.0222	15.26	0.1517	-0.20	14.63	0.15	0.99
Mean	9.84	0.0291	9.99	0.3030	-0.15	9.59***	0.30	3.03

Analysis by square root of within class mean square, CV: coefficient of variation

***: $p<0.001$, sd: standard deviation

A: radiographs with 20x magnification devided by 20x

B: radiographs without magnification

years), with adult periodontitis reporting or referred to the patient population of the Periodontal Clinics of Dental School, Kaoshiung Medical University from 1986 to 1999. Clinical examination of periodontal charting comprised the age, sex, and a questionnaire of dental history (including causes of missing tooth, gingival index, initial probing pocket depths and clinical attachment levels. One hundred and seventy-eight individuals with the routine 14 periapical radiographs including tooth distortion, poor radiographic quality, restoration obliterating the cemento-enamel junction (CEJ), and overlapping in either teeth or CEJ measurements, which produced unreadable measurement points, were excluded from the study samples.

Measurements of digital scanning radiograph

The periapical radiographs were taken by the use of a parallel technique and XCP film holders with long cone indicator. A random selection of a total 20 radiographic assessments of mesially and distally alveolar bone loss, which were made on the radiographs (10-magnification), were scanned by a scanner (Nikon LS-1000, Adaptec AHA-2940 UW SCSI card) at 1350 dpi (dots / inch) and 256 shades of gray scale. All the scanned radiographs were displayed on a PC monitor under a 10x image enlargement and measured by the IBM compatible personal computer system (Microsoft Windows 98; Adobe Photoshop 5.0) equipped with the Microstation 95 Image software (MIS) (Windows x 86, Bently Systems, Inc., USA). The distance between the enlarged CEJ to alveolar crest (AB), and CEJ to most apical point of root apex (AC) was measured, mesially and distally (Fig. 1) by two senior, experienced postgraduate dentists. The proximal radiographic alveolar bone loss (RABL) was defined as bone defects in which the distance between CEJ and AC should be at least 2 mm. The radiographic measurement of each tooth was measured, mesially and distally, in mm. The deeper defect was selected as measuring data and the ratio of RABL to root length was calculated by percentage. The three reference points on the root surface were labeled A, B, and C. The radiographic images of the CEJ, the alveolar crest and root apex were used as the three reference points for the calculation of the radiographic linear measurements of RABL. The alveolar bone crest was recorded as the most apical point of each mesial or distal defect. The distance of AB (radiographic alveolar bone loss, RABL), AC (root length) was measured by calculating with the IBM compatible personal computer system program to determine the % of AB/AC. The coordinates generated by the MIS for three points were AB and AC, respectively (Fig. 1). So, the equation of RABL (%) was calculated by following procedure :

$$X'=10X;\ Y'=10Y$$

$$RABL=[(X'-2)\times 10]/[(X'-2)\times 10]+Y']\times 100\%$$

The equation of RABL, based on the above, was then entered into the computer system connected to the MIS. The percentages of linear measurements of RABL were measured under a Nikon LS-1000 Scanner at 10-magnified radiographs by means of a computer system equipped with the MIS system. The MIS calculated the ratio of AB (alveolar bone loss) to AC (root length) in 10-magnification as $[(X'-2) \times 10] / [(X'-2) \times 10) +Y'] \times 100\%$. The % of RABL was referred as the radiographic alveolar bone loss (Fig. 1). Duplicate measurements were obtained for each tooth. The data were analyzed to provide percentages, means, and standard deviations.

All measurements were numerically coded and results were processed and analyzed by computer system equipped with the MIS described earlier [12]. Usually, all the collected data from 14 standard periapical radiographs of each tooth, and the mean RABL of proximal areas were analyzed for both of maxillary and mandibular molars.

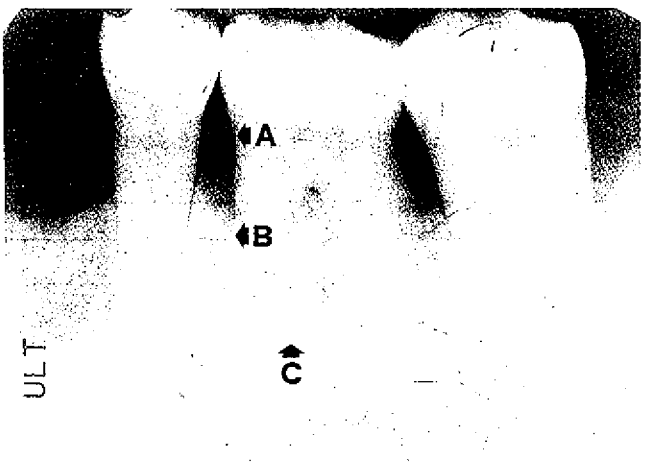

Fig. 1. The distance between the enlarged CEJ (point A) to alveolar crest (point B) referred as AB (height of bone loss) and CEJ to most apical point of root apex (point C) as AC (root length) was calculated by percentage (%). The radiographic images with magnification (10x) were measured and calculated by computerized system equipped with the Microstation 95 Image Software (MIS).

Data analysis

All the measurements were performed and read by two examiners (examiner l, principal examiner; examiner 2, post-graduate student), with a separation time of three weeks, different tooth groups and as established by double reading of 20 molars in 10 individuals (Tables 2, 3). The means of RABL measured by DSRIA for each molar tooth were compared based on the inter- and intra-examiners' data. The means and standard deviations of these measurement data from the DSRIA were used as the statistical value for the comparisons of each molar between the inter- and intra-examiners' groups. The reliability coefficients were used to compare the consistency and reliability between the intra- and the inter-examiners' groups using the DSRIA for each tooth of maxillary, mandibular and of both molars. A statistically significant difference was defined as $p<0.05$.

RESULTS

Table 1 shows the differences of measuring radiographic data from the known length of 10 pairs of photographs by 5 different well-trained, experienced operators (postgraduate dentists) following the repeated assessments with and without magnification. The standard deviation for measurements on radiographs without magnification was 0. 30 mm, while that of the radiograph with magnification was 0.03 mm only. The standard deviation of radiograph with magnification was only 9.59 % of that of without magnification. Results demonstrated that there was a significant difference of heterogeneity in the standard deviation of radiographic measurements between the radiographs with 20x and without magnification. A coefficient of variation (SD/Mean × 100%) also showed heterogeneity (9. 59%) between radiographs with (20x) and without magnification. The finding of present study showed that radiographs with magnification provided more accuracy in measuring the linear alveolar bone level than those radiographs without magnification.

Tables 2 and 3 present the inter- and intra-examiners' data from the measurements of linear bone loss between radiographs with and without magnification for maxillary and mandibular molars when the DSRIA is used as measuring the standardized paralleling radiographs. The reliability coefficient of inter-examiners' group in measuring RABL of maxillary, mandibular and of both molars using the DSRIA were 0.992, 0.995, and 0.986, respectively (Table 4). A similar finding was noted in the intra-examiners' group to the effect that the reliability coefficient, with repeated measurements undertaken at a 3-week interval in maxillary, mandibular and of both molars, were 0.992, 0.995, and 0.986, respectively (Table 4).

A similar result was also found to the effect that the intra-class reliability coefficient of maxillary, mandibular, and of both molars was significantly different from zero ($p<0.001$). Compari-

Table 2. Inter- and intra-examiners' data from the measurements of linear bone loss of radiographs with magnification in maxillary molars

Maxillary molars	Ex. 1		Ex. 2	
	1st time	2nd time	1st time	2nd time
Case 1	43.23	41.96	44.37	43.12
Case 2	54.93	56.18	51.24	50.47
Case 3	15.21	15.71	14.77	16.13
Case 4	38.13	40.08	41.52	42.76
Case 5	64.34	61.91	64.15	63.92
Case 6	52.36	50.91	49.38	51.25
Case 7	25.25	24.88	27.27	25.63
Case 8	x	x	x	x
Case 9	28.34	29.71	31.46	29.73
Case 10	19.51	20.24	18.75	18.97

Ex. 1: Examiner 1; Ex.2 Examiner 2.

Table 3. Inter- and intra-examiners' data from the measurements of linear bone loss of radiographs with magnification in mandibular molars

Maxillary Molars	Ex. 1		Ex. 2	
	1st time	2nd time	1st time	2nd time
Case 1	38.98	40.98	39.34	40.26
Case 2	64.52	64.29	66.07	66.55
Case 3	21.20	21.43	21.52	21.82
Case 4	39.73	37.14	38.81	37.54
Case 5	63.36	64.63	63.15	64.97
Case 6	37.94	35.76	38.72	36.23
Case 7	28.97	30.96	30.20	31.01
Case 8	32.96	33.43	33.61	33.14
Case 9	71.62	70.46	71.07	69.17
Case 10	27.38	23.44	27.68	24.39

Ex. 1: Examiner 1; Ex.2 Examiner 2.

Table 4. The reliability coefficients of inter- and intra-examiners' groups in measuring radiographic alveolar bone loss (RABLo) in maxillary, mandibular, and of both molars using the digital scanning radiographic image analysis (DSRIA)

Molar Location	Reliability coefficients	Significant level from 0
	Inter-examiners' group	
Maxilla	0.992168	$p<0.001$
Mandible	0.994761	$p<0.001$
Both arches	0.986271	$p<0.001$
	Intra-examiners, group	
Maxilla	0.992164	$p<0.001$
Mandible	0.994831	$p<0.001$
Both arches	0.986304	$p<0.001$

son of the results between the inter- and intra-examiners' reliability coefficient demonstrated that the inter-class reliability coefficient in maxillary, mandibular, and of both molars was slso significantly different from zero ($p<0.001$) (Table 4).

DISCUSSION

The DSRIA, a newly developed technique by our research group, is a combined procedure of digital scanning, computer-aided management using a Microstation 95 image software and archiving system for intra-oral x-ray image. Therefore, the presented data was the first information about the assessment of alveolar bone height. Our pilot study diverging on the higher consistency and reliability of this new technique demonstrated that accurate detection in the periodontal osseous defects, limited to measuring linear alveolar bone height, was not only of a high specificity but also a greater reliability.

Limited information is available, about on

whether radiographic analysis with enlargement is more accurate in the assessment of periodontal alveolar bone defects than radiographs without enlargement. Present data reveal that a coefficient of variation (SD/Mean $\times 100\%$; square root within class mean square) for the standard deviation shows a significant difference of heterogeneity (9.59%) between radiographs with 20x and without magnification. This means that the accuracy of measuring periodontal osseous defects by periapical radiographs with 20x magnification (with a 0.029 mm of mean SD) was significantly higher than radiographs without magnification (with a 0.30 mm of mean SD) (Table 1). Therefore, radiograph with magnification was the most appropriate method in the measuring ability and provided the most accurate imaging of alveolar bone defects when compared to the radiographs without magnification. The present study confirmed the study by Akesson et al. [16], who reported that periapical radiography with magnification proved to be more accurate in the measuring of periodontal osseous defects than conventional periapical radiography without enlargement, regardless of the jaw location and tooth type.

Evaluation of the periodontal bone defects using the digital scanning radiographic image analysis (DSRIA) showed that there was a statistically significant difference from zero between the intra- and inter-examiners' groups with a high value of reliability coefficient ($r=0.992$, $p<0.001$) in maxillary molar. A similar trend was noted for the comparison between the intra- and inter-examiners' groups using the DSRIA. It also revealed a statistically significant difference from zero ($r= 0.995$, $p <0.001$) in mandibular molar and both arches ($r=0.986$, $p<0.001$), respectively (Table 4).

Goldman and Stallard [17] reported that the measurement of alveolar bone loss is usually underestimated due to poor radiographic visibility of the marginal bone crest. Results from recent studies revealed that there was an underestimation of bone loss regardless of the use of a digital system or conventional intraoral radiographs [18, 19]. In addition, they found that the results of the underestimation for the 2nd molar were poorer than the 1st molar. We did not compare the difference between the 1st and 2nd molar in the present study. A relatively higher reliability coefficient and statistically significant different from zero ($p<0.001$), between the intra- and inter-examiners' group as well as in maxillary, mandibular and of both molars, provided strong evidence to support the view that DSRIA is a valuable and reliable method in measuring alveolar bone height. Further studies are needed to evaluate the diagnostic value, particular in the subtle change of bone density in periodontal osseous defects and implant dentistry.

The intra-examiners' group was expected to coincide closely to the inter-examiners' group indicating that the accurate performance of periodontal bone levels is possible from standard periapical radiograph taken when DSRIA technique is employed. It was concluded that periapical radiograph using digital scanning radiographic image analysis has the potential to be a more accurate and reliable measurement in the linear estimation of periodontal bone levels.

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應用數位掃瞄X光影像分析法測量牙周骨高度的可靠性及一致性－初步研究

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本研究目的乃是應用數位掃瞄X光影像分析法(digital scanning radiographic image analysis，DSRIA)評估齒槽骨垂直高度測量值的一致性(consistency)及可靠性(reliability)。取材自本院178位牙周炎患者中，隨機取樣10個患者的20個大臼齒(10個上顎大臼齒及10個下顎大臼齒)的標準平行法的根尖X光片，選取的20張樣本經由DSRIA的方法分別由牙周病醫師進行檢查者本身 (intra-examiner)與檢查者間(inter-examiner)每間隔3週的重覆測量齒槽骨垂直高度(radiographic alveolar bone loss, RABLo)。根據檢查者本身及檢查者間重覆測量的平均值(mean)及標準差(standard error)進行上顎大臼齒、下顎大臼齒及上、下顎大臼齒的計算分析結果，每組再以利用依賴係數 (reliability coefficient)，了解結果的一致性。結果發現以DSRIA方法分別進行上顎、下顎及上下顎三組的檢查者內及檢查者間的分析結果，依賴係數介於0.986~0.995之間 ($p<0.001$; 顯著地不同於0)，顯示相當高的一致性。結論顯示經由數位掃瞄X光影像分析法測量標準平行法的根尖X光片牙周齒槽骨高度，仍具有相當高的可靠性及一致性。

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