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ORIGINAL ARTICLE

Comparison of the reproducibility of storage phosphor and film bitewings for assessment of alveolar bone loss

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Abstract

Objective. To compare bitewing storage phosphor images and a digital measuring method with bitewing films and an analog measuring method with regard to the reproducibility of measurements of alveolar bone loss. ***Material and methods.*** Nine participants randomly selected from an epidemiological study were radiographically examined using two modalities: bitewing SP images and bitewing films. A digital measuring method was used on the bitewing SP images and an analog measuring method on the bitewing films. Alveolar bone loss was measured at 12 index sites in the premolar/molar region per participant and modality. One hundred measured sites on each modality were assessed twice by three observers. Paired *t*-test values and intra-class correlation coefficient (ICC) were computed. ***Results.*** Comparison of the mean absolute difference of alveolar bone loss between the digital and analog measuring methods demonstrated comparable results ($p = 0.53$). The absolute difference in millimetres between 1st and 2nd measurements was comparable for two observers and statistically different for one. Intra-observer performance between 1st and 2nd measurements was comparable for the digital (ICC = 0.85) and analog (ICC = 0.83) measuring methods. Inter-observer agreement for the digital measurements was higher (ICC = 0.79) than for the analog measurements (ICC = 0.64). ***Conclusions.*** The study demonstrates that digital and analog measuring methods are comparable with regard to absolute alveolar bone measurements and intra-observer agreement. Inter-observer comparison demonstrated significantly higher agreement for the digital measurements. Based on the overall results, the modalities with the measuring methods utilized are comparable when measuring minor alveolar bone loss.

Key Words: *Alveolar bone loss, bitewing radiography, dental radiography, digital radiography, observer variation*

Introduction

High reproducibility is important when measuring alveolar bone in clinical studies in periodontology and implantology. It is also important when evaluating changes in alveolar bone level in epidemiological studies over even longer periods of time in research on anthropological scull material. The traditional method for measuring alveolar bone loss on conventional films has been to use calibrated rulers or a vernier calliper. In several studies, measurements have been compared on panoramic and intra-oral films in healthy patients or patients with periodontal disease [1–4]. It has been shown that panoramic radiography alone is not sufficient for diagnosing alveolar bone loss, but should be combined with intra-oral radiographs in areas of interest [1–4]. Over the past few years, digital measuring in digital images using computer software has become more common in clinical longitudinal studies, and in time will probably replace the analog measuring methods used in clinical and anthropological studies. In the recent literature on alveolar bone loss assessments, digital imaging to films in intra-oral and panoramic radiography has been compared but with varying results. A few studies have used digitized conventional films in assessing alveolar bone loss [5–7], in some a storage phosphor system [8–10], and in others direct digital radiography with sensors [10–12].

In anthropological and clinical research, it is of general interest to find out whether digital measurements on digital images are comparable with analog measurements on conventional films with regard to

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alveolar bone measurements, and it would be of interest also for professions other than dentistry, such as physical anthropologists, to apply a digital method in measuring alveolar bone loss independently of the software used in a particular digital imaging system. To our knowledge, no study has evaluated alveolar bone loss measurements on films and digital images exposed simultaneously, nor, as far as we know, has an analog measuring method and a digital measuring method been compared with specially developed software independently of software from image scanner manufacturers. The aim of this study was thus to compare bitewing storage phosphor images and a digital measuring method with conventional bitewing films and an analog measuring method with regard to reproducibility of alveolar bone loss measurements.

Material and methods

Radiographs were obtained at the University of Oslo of nine randomly selected participants from the epidemiological study "The Oral Health of 35-Year-Old Oslo Citizens 2003" (approved by the Norwegian Ethics Committee 08.09.2001, ref. no. S-01166). Most of these individuals show no signs of periodontal disease. They were radiographed consecutively by experienced radiology technologists under normal clinical practice conditions at the Department of Maxillofacial Radiology using two different modalities: bitewing SP image plates and bitewing films. A conventional dental film (Insight; Eastman-Kodak Co., Rochester, N.Y., USA) without the lead foil and a Digora SP image plate (Soredex Medical Systems, Helsinki, Finland) were sealed in a protective envelope, previously described by Møystad et al. [13]. The package was placed in a Digora bitewing holder and exposed simultaneously for 0.16 s. Identical exposures were obtained in this manner. One premolar and one molar posterior bitewing image were exposed on each side of the participant. A metal pin of known length was mounted vertically in the molar region on a dry scull and a Digora SP image plate was exposed under the same conditions as mentioned above. This image was used to calibrate the measurements in the PC program for the magnification factor. The X-ray source was a Siemens Heliodent MD (Sirona, Bensheim, Germany) operating at 70 kV and 7 mA.

Digital radiography

The exposed Digora SP image plates were scanned using a Digora FMX scanner and quality assessed using the Digora software 2.5 (2004). The SP images were converted into TIFF (Tagged Image File Format) format with a spatial resolution of 628×466 pixels and 256 grey levels, and assessed on a 19" Dell Trinitron computer monitor (Sony, Tokyo, Japan) with a spatial resolution of 1024×768. A measuring computer program developed at the Department of Maxillofacial Radiology, University of Oslo, was used in the reading. The computer program was developed with simple image tools such as distance and area measurements, magnification and brightness contrast settings. The area of interest was magnified 2-fold. Brightness and contrast were fixed for all measurements, which were recorded with a precision of 0.01 mm.

Film radiography

The exposed films were developed in an automatic processor (Procomat Junior T 380; Elema-Schönander AB, Solna, Sweden) and assessed using a light box (REX Messinstrumentebau GmbH, Babenhausen, Germany) with fixed intensity and an X-viewer with a $2 \times$ magnification (X-produkter, Malmö, Sweden). The measurements were taken with a vernier calliper (Somet, Czech Republic) and recorded with a precision of 0.01 mm.

Assessment and observers

Both readings were done under the same conditions, i.e. in a darkened room in 1-h sessions, for both modalities. An intervening time of at least 7 days was allowed between each modality and reading. Three observers (two dental radiologists and one periodontist) with radiographic experience ranging between 9 and 35 years were calibrated beforehand about how to assess the anatomical structures (top of the alveolar bone septum and the cemento-enamel junction; CEJ). Alveolar bone loss was measured by direct measurements in millimetres from the top of the alveolar bone septum to the CEJ [5] on the mesial surface of the 2nd premolar, and the mesial and distal surface of the 1st molar in each quadrant, i.e. 12 index sites per participant and modality. The material comprised radiographs from individuals with minor bone loss. Mean bone loss measured for all three observers was 1.25 mm, with a range from 0 mm to 3.9 mm. The total number of surfaces assessed was recommended by a statistician (LS) to be 100 per modality and performed twice by each observer. In all, each observer carried out a total of 400 measurements. Intra-observer performance was defined as the difference between two readings by the same observer.

Statistics

All data were statistically processed using the SPSS software version 15.01 for Windows (Chicago, Ill., USA). Paired sample *t*-test was used when comparing means. A significance level of 5% was used for each comparison. To estimate inter-observer performance, the mean of the first measurements was

used. The correlation between two readings by one observer and between the three observers was analyzed using the intra-class correlation coefficient (ICC) for each modality, with a 95% confidence interval. The highest possible value of ICC is 1.0, and the closer to 1.0 the higher the precision.

Results

The digital measuring method on bitewing SP images demonstrated comparable measurements with the analog measuring method on bitewing film for the averaged measurements of all three observers (Table I). The results revealed significantly different measurements between the methods with regard to observer 3.

Intra-observer agreement

Intra-observer agreement, demonstrated by the ICC between 1st and 2nd measurements, for each modality and observer is presented in Table II. It was comparable for the digital (ICC = 0.85) and analog (ICC = 0.83) measuring methods regarding the averaged measurements for all three observers. Observer 1 demonstrated comparable measurements regarding bitewing SP images ($p = 0.84$) and significant different measurements ($p < 0.0001$) regarding bitewing film. Observer 2 and observer 3, however, demonstrated comparable measurements regarding bitewing film ($p = 0.19$ and $p = 0.75$, respectively) and significantly different measurements regarding bitewing SP images ($p < 0.0001$). Mean intra-observer bitewing SP measurements ranged from 1.11 mm to 1.54 mm and mean intra-observer bitewing film measurements from 0.88 mm to 1.51 mm.

Inter-observer agreement

Measurements on bitewing SP images revealed a higher ICC for all three observers (ICC = 0.79) than measurements on bitewing film (ICC = 0.64), demonstrating higher inter-observer agreement when the digital method was used (Table III). As the confidence interval did not overlap, the difference between methods was significant regarding inter-observer agreement. The pair-wise ICCs with confidence intervals for the two modalities are presented in Table III.

Table I. The absolute difference in alveolar bone loss (mm) between 1st and 2nd measurements by the observers with regard to digital (bitewing SP) and analog (bitewing film) measuring methods. Number of measured sites for each observer = 100.

	Bitewing SP		Bitewing film		
	Mean	SD	Mean	SD	*p*-value
Observer 1	0.17	0.19	0.18	0.16	0.86
Observer 2	0.24	0.21	0.28	0.27	0.19
Observer 3	0.20	0.19	0.12	0.11	0.001
Mean 1,2,3	0.21	0.12	0.20	0.11	0.53

Table II. Intra-observer agreement demonstrated by intra-class correlation coefficient (ICC) between 1st and 2nd measurements with regard to digital (bitewing SP) and analog (bitewing film) measuring methods.

		Bitewing SP	Bitewing film
Observer 1	ICC	0.85	0.91
	95% CI	0.79–0.90	0.87–0.94
Observer 2	ICC	0.87	0.68
	95% CI	0.81–0.91	0.56–0.77
Observer 3	ICC	0.82	0.91
	95% CI	0.74–0.87	0.88–0.94

Discussion

This study demonstrates that the digital measuring method on bitewing SP images is comparable with the analog measuring method on bitewing film for the averaged measurements. This is supported by Nair et al. [14], who also found comparable results for crestal bone evaluations when Ektaspeed film and a CCD system Sidexis were evaluated.

Differences in projection geometry between examinations using the same method or between methods during the same examination can cause methodological errors that may influence measurements of alveolar bone loss. In a review of the reliability of alveolar bone measurements, Benn [15] discusses the difficulties in evaluating small amounts of bone loss in particular and concludes that more accurate and simple techniques are needed with repositionable film-holders and an automatic computer-based measuring system. In the present study, identical SP images and films were obtained simultaneously in a Digora bitewing holder, a method that eliminates projection and exposure differences between the methods.

It is well known that comparison between modalities is observer dependent when evaluating marginal bone levels. In the present study, three different observers measured alveolar bone loss. The pair-wise ICCs for the two modalities revealed a significant

Table III. Inter-observer agreement demonstrated by intra-class correlation coefficient (ICC) with regard to digital (bitewing SP) and analog (bitewing film) measuring methods. The 1st measurements of the observers were computed.

		Bitewing SP	Bitewing film
Observers 1-2	ICC	0.82	0.63
	95% CI	0.74–0.87	0.50–0.74
Observers 1-3	ICC	0.78	0.72
	95% CI	0.68–0.84	0.61–0.80
Observers 2-3	ICC	0.79	0.56
	95% CI	0.70–0.85	0.41–0.68
Mean	ICC	0.79	0.64
	95% CI	0.73–0.85	0.54–0.73

difference for observer 2. Clearly, the present result on inter-observer agreement may depend on the result of observer 2. Interestingly, the present study has demonstrated significantly higher inter-observer agreement for bitewing SP measurements than for bitewing film, indicating that the digital measuring method on bitewing storage phosphor images may be more reproducible than the analog method in the evaluation of minor alveolar bone loss. Our observations on inter-observer agreement are supported by Svanæs et al. [16] in a study on caries diagnosis. They found a significantly lower inter-observer variability for intra-oral storage phosphor images than for films in the detection of caries. When the reproducibility of two different systems is to be compared, it is essential that the statistical power is adequate. In the present study design, statistical power was calculated based on an adequate number of evaluations when three observers, representing dental radiologists and periodontists with different experience, were included in the study. In many studies where multiple observers have been used, it is notable that all observers have been selected from among staff members and experts from a single specialist department [17]. According to Hintze et al. [17] results from such studies are not more generalizable than results from studies with fewer observers. However, future research including a representative group of dentists is recommended to find out whether the present promising results on inter-observer agreement are valid for the general dentist.

Individual experience with a specific modality and measuring method is probably an influential factor on individual performance. Interestingly, in our study the observers who were most experienced with bitewing films reflected higher intra-observer agreement with the analog measuring method, whereas the most experienced observer with the digital modality had higher intra-observer agreement with the digital measuring method. There is therefore a possibility that the experience of the observers might have influenced the outcome of our measurements.

Several authors have discussed the possible influence of experience and observer performance on vertical measurements of teeth and alveolar bone. Wolf et al. [6] found the distance between the CEJ and the alveolar crest to be significantly influenced by examiner experience in digitized bitewings, where the more experienced observer showed lower measurement variability. Åkesson et al. [2] found systematic variation of observer performance; one observer had the highest mean bone loss estimates and another the lowest mean estimates with the three modalities bitewing, periapical and panoramic film. They concluded that the diagnostic yield of the radiographic methods was substantially affected by observer performance. Thanyakarn et al. [18] reported that the accuracy and precision of tooth-length measurements on panoramic radiographs were highly influenced by observer performance.

The participants in the present study were selected from an epidemiological study on healthy 35-year-olds in which few of the individuals showed any signs of periodontal disease. According to the literature referred to in a review by Benn [15], the preset limit of pathological bone loss varies from greater than 1.0 mm to over 3.0 mm. In our study, mean bone loss measured for all three observers was 1.25 mm, ranging from 0 mm to 3.9 mm. The minimal bone loss in our material is consistent with the material of Papapanou et al. [19], who found that pronounced bone loss was non-existent in ages below 35 years. The bone loss measurements of the sites in our study were small for both modalities, and thus our results are applicable only in the case of individuals with little or no bone loss. Although we found significantly different measurements between the methods, the differences in millimetres might not be of any clinical relevance.

The digital measuring method in our study applied specially designed software, independently of software from image scanner manufacturers. This may be an advantage in sciences other than odontology, e.g. physical anthropology, which may use digitized films during measurements. In previous anthropological field studies, film radiography has been most commonly used as far as we know [20]. Often there have been long time intervals between film exposures and film processing, which has been a limitation with regard to necessary re-exposures of bad quality radiographs. With digital radiography, anthropological field work may be easier to conduct in the future. There is no longer a need for standardized image processing and developing solutions, and digital images appear on the monitor after a few seconds. In an ongoing anthropological study of medieval and Stone Age skull material, alveolar bone is measured using the present digital measuring method.

In conclusion, the present study has shown that digital and analog methods are comparable with regard to the reproducibility of absolute alveolar bone loss measurements and intra-observer agreement. Inter-observer comparison has demonstrated significantly higher agreement for the digital measurements on the bitewing SP images. Measurements with the digital measuring method on storage phosphor images can be considered a good alternative to the conventional analog measuring method on film when measuring minor alveolar bone loss.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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