Evaluation of diagnostic accuracy of conventional and digital periapical radiography, panoramic radiography, and cone-beam computed tomography in the assessment of alveolar bone loss

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Abstract

Background: To evaluate the diagnostic accuracy of different radiographic methods in the assessment of proximal alveolar bone loss (ABL). **Materials and Methods:** ABL, the distance between cement-enamel junction and alveolar bone crest, was measured in 70 mandibular human teeth – directly on the mandibles (control), using conventional periapical radiography with film holders (Rinn XCP and Han-Shin), digital periapical radiography with complementary metal-oxide semiconductor sensor, conventional panoramic, and cone-beam computed tomography (CBCT). Three programs were used to measure ABL on the images: Image tool 3.0 (University of Texas Health Sciences Center, San Antonio, Texas, USA), Kodak Imaging 6.1 (Kodak Dental Imaging 6.1, Carestream Health®, Rochester, NY, USA), and i-CAT vision 1.6.20. Statistical analysis used ANOVA and Tukey's test at 5% significance level. **Results:** The tomographic images showed the highest means, whereas the lowest were found for periapical with Han-Shin. Controls differed from periapical with Han-Shin ($P < 0.0001$). CBCT differed from panoramic ($P = 0.0130$), periapical with Rinn XCP ($P = 0.0066$), periapical with Han-Shin ($P < 0.0001$), and digital periapical ($P = 0.0027$). Conventional periapicals with film holders differed from each other ($P = 0.0007$). Digital periapical differed from conventional periapical with Han-Shin ($P = 0.0004$). **Conclusions:** Conventional periapical with Han-Shin film holder was the only method that differed from the controls. CBCT had the closest means to the controls.

Keywords: Alveolar bone loss, cone-beam computerized tomography, conventional periapical radiography, diagnosis, panoramic radiography

Introduction

Alveolar bone height is the distance between the cement-enamel junction (CEJ) and the alveolar bone crest (ABC), along a line parallel to the long axis of the tooth.[1,2] This distance indicates whether there is alveolar bone loss (ABL) and bone alterations due to periodontal disease. Although studies showed considerable variation in this distance, from 0 to 3 mm,[3,4] a 2 mm distance is more often adopted as the norm for patients without periodontal disease.[4]

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The diagnosis of periodontal diseases requires a careful clinical examination that takes into account the clinical history and associated signs and symptoms. In addition, radiographic examination is a fundamental tool to assess morphological and pathological changes in the periodontium, to assist the diagnosis, treatment planning, and prognosis of periodontal diseases.[5,6]

The most used radiographic methods in the diagnosis of periodontal diseases are panoramic radiography, bitewings and periapical radiography,[3,7] despite their limitations - subjectivity of interpretation, image overlapping, and reduced sensitivity in detecting marginal bone changes.[8]

Constant technological development brought into dentistry other important imaging methods, such as digital radiography and cone-beam computed tomography (CBCT). Digital radiographic methods facilitate clinical practice, given that they eliminate chemical processing, reduce radiation exposure, and the images can be manipulated with the use of software.[9] This possibility of enhancing digital images optimizes diagnosis, unlike the static images of conventional films, which cannot be manipulated or enhanced.[10,11] However, as the geometry of digital images is still in two-dimension, the interpretation of intraoral and panoramic radiography do not benefit greatly from this aspect.[12]

Cone-beam computed tomography, on the other hand, provides images with excellent quality and accuracy, the

structures can be seen in three-dimension at any angle, which allows analysis without distortion, and measurement of bone loss even of the buccal and lingual/palatal faces, a possibility not possible with other types of images.[3,5] However, du Bois *et al*.[2] assert that only about 3% of current studies in dentistry examine the applications of CBCT in periodontics. Does CBCT is so many good other image methods? CBCT may be unnecessary for interproximal ABL.

The aim of this *in vitro* study was to evaluate the diagnostic accuracy of conventional periapical radiography taken with film holders Rinn and Han-Shin, digital periapical radiography with complementary metal-oxide semiconductor sensor (CMOS), panoramic radiography, and CBCT in the measurement of ABL.

Materials and Methods

The study was approved by the Institutional Review Board/ Independent Ethics Committee of the State University of Maringá (Protocol 0655142.7.0000.0104). The sample consisted of 70 teeth from 10 macerated human mandibles of the university's Department of Morphophysiology Sciences, each mandible with varied number of teeth.

The control method of measuring ABL consisted of determining the linear distance between the CEJ and the ABC on the interproximal surface of the teeth (the CEJ-ABC distance), with the use of a digital calliper accurate to 0.01 mm (Lee Tools®, Rio de Janeiro, Brazil). The experimental methods consisted of measuring ABL using conventional periapical radiography with film holders (Rinn XCP and Han-Shin), digital periapical radiography with CMOS, panoramic radiography, and CBCT [Figure 1]. For better standardization were placed in small metal spheres in the CEJ and another peak of the ABC.

Conventional periapical radiographs were obtained using the paralleling technique with Rinn XCP film holder (Dentsply, USA) at a 40 cm focal length, and bisecting technique with Han-Shin film holder (Maquira®, Maringá, Brazil) at a 20 cm focal length. Particular care was taken in order to minimize discrepancies among radiographs, by standardizing the geometrical projection of the X-rays, the alignment of the images, and contrast and density of the images. The bitewing technique was not performed because ABL was extensive in some teeth and could cut in the image.

Digital periapical radiographs were taken with the film holder provided by Kodak RVG 6100 digital radiography system (Carestream Health®, Rochester, NY, USA). The digital periapical radiographs was measured using the equipment's own software (Kodak Dental Imaging 6.1, Carestream Health®, Rochester, NY, USA). The files are saved according to the manufacturer's specifications.

Panoramic radiographs were obtained with a conventional X-ray machine (Orthoralix 9200 GENDEX, Dentsply®, Des Plainnes, USA) using Kodak T-Mat G/RA films (15 × 30 cm, Carestream Health®, New York, USA) with their metallic cassette and intensifying screen (Kodak Lanex Medium Extraoral Imaging Screens X-Omat). Using alignment lights, the mid sagittal plane of the mandibles was positioned perpendicularly to the ground and the occlusal plane parallel to the ground.

Calibration of panoramic radiography, conventional and digital periapical radiography was made using an aluminum step wedge (8 steps) with 1 mm increment and 5 mm thickness.

Conventional radiographs were processed in an automatic processor (Revell X-TEC, Londrina, Paraná, Brazil).

Cone-beam computed tomography images were obtained using an i-CAT scanner (Hatfield, PA, USA). For most favorable detailing of root structures, the study used a 14-bit grey scale, field of view of 6 cm, voxel of 0.125 mm, and 36.2 mAs exposure time. All radiographic and tomographic images were taken by the same operator, a specialist in dentomaxillofacial radiology. The files are saved according to the manufacturer's specifications.

Panoramic radiographs and conventional periapical radiographs were digitized using a scanner and a transparency adaptor (HP Scanjet G4050, Hewlett-Packard Company®, Washington, USA) with optical scanning resolution of up to 4800 dpi.[13-15] Conventional radiographs were scanned at a resolution of 300 dpi and archived in uncompressed tagged-image file format (TIFF). The TIFF format is the best image format for digitized images, as if it were transformed into digital imaging and communications in medicine (DICOM) the details will be lost.[16,17]

Alveolar bone loss from digitized conventional periapical radiographs and digitized panoramic radiographs was measured using Image Tool 3.00 software (University of Texas Health Sciences Center, San Antonio, Texas, USA),[18,19] according to Gürdal *et al*.[20] the best image format using the Image tool software was the TIFF format. For CBCT images [Figure 2], ABL was measured using the equipment's own software (i-CAT Vision, Imaging Sciences International, LLC, Pennsylvania, USA). Measurements were made parallel to the long axis of the tooth, on the proximal surfaces.[21,22]

File formats were determined by the image generated by the programs, except the conventional radiographs that had to be scanned format, that TIFF considered best for scanned images was used.[16,17] We chose to use the best file format and better resolution for each image type. All measurements were made by a single radiologist, experienced with the use of the mentioned programs, a specialist in dentomaxillofacial radiology, and were analyzed again with a 1 week interval between them.

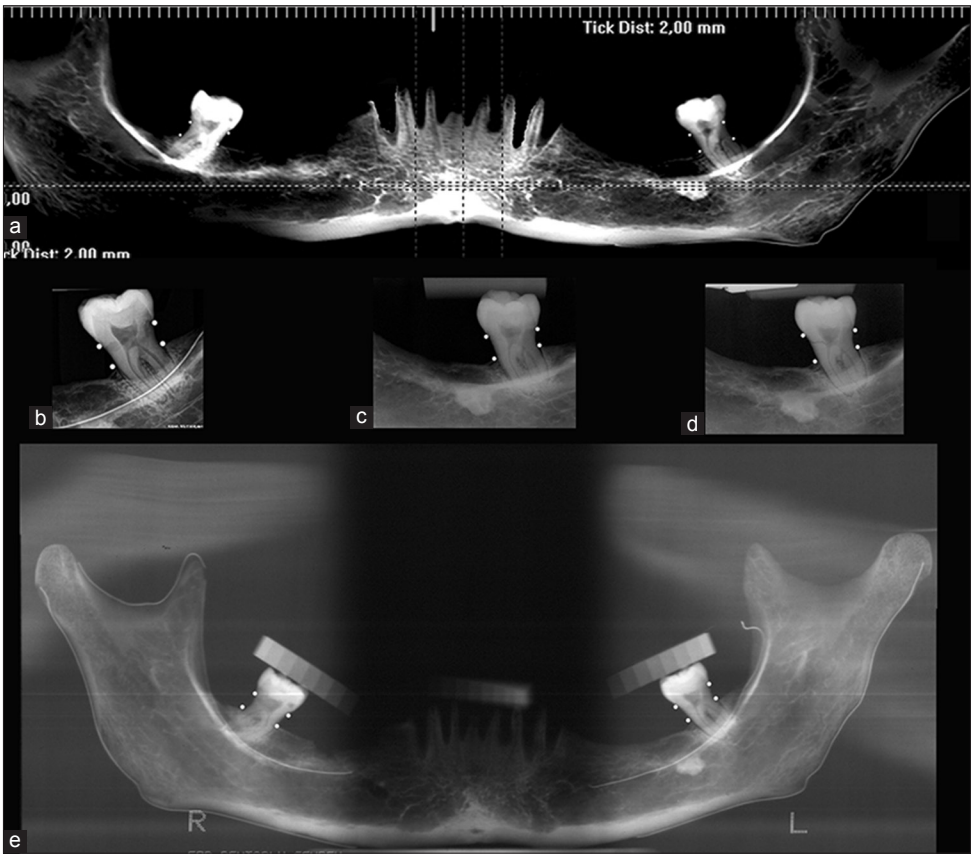

Figure 1: (a) Cone-beam computed tomography image. (b) Digital periapical radiography with complementary metal-oxide semiconductor sensor. (c) Conventional periapical radiography with film holders Han-Shin. (d) Conventional periapical radiography with film holders Rinn XCP. (e) Panoramic radiography

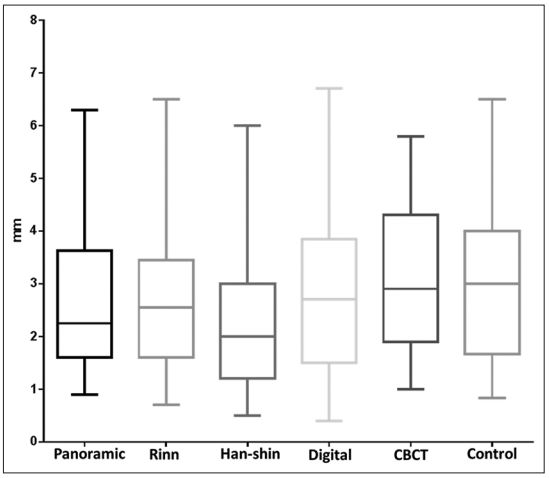

Figure 2: Means (in mm) of different radiographic methods

Intra-examiner reliability was verified by weighted kappa test (κ_W). Intra-examiner coefficient was 0.843, the strength of agreement was very good according Altman[23] [Table 1], nevertheless the means of these two measurements were used for statistical analysis for greater reliability. Data were subjected to ANOVA and Tukey's test at 5% significance level, using GraphPad Prism 6.0 (GraphPad Software, San Diego, CA, USA) and Minitab 15.0 (Minitab Inc, State College PA, USA).

Table 1: The *K* value can be interpreted as follows (Altman, 1991)

Value of *K*	Strength of agreement
<0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Very good

Results

The highest means of VBL were found for the actual measures using the calliper, the control method, and for the CBCT images, whereas the lowest ones values were for the images taken with the film holder Han-Shin [Table 2 and Figure 1].

Multiple comparisons of means using Tukey's test revealed that statistical differences [Table 3] were between control method and periapical using Han-Shin film holder ($P < 0.001$), but not between control and the other methods. The results of CBCT were different from those of panoramic radiographs ($P = 0.0130$), periapical with Rinn XCP film holder ($P = 0.0066$), periapical with Han-Shin film holder ($P < 0.0001$), and digital periapical

radiographs ($P = 0.0027$). Periapical with film holders were different from each other ($P = 0.0007$). Digital periapical differed from periapical with Han-Shin film holder ($P = 0.0004$).

Discussion

Radiographic examination, along with clinical examination, is essential in the diagnosis of periodontal diseases, in determining their prognosis, and in assessing treatment outcome.[3-6] Due to its relevance, this study aimed to evaluate the best radiographic method for measuring ABL.

In this study the results of periapical radiographs using the Rinn XCP film holders and Han-Shin were different from those Forsberg and Halse[22] and Hayashi *et al.*[24] Although these authors concluded that both film holders show comparable accuracy if Han-Shin is correctly used and set at the right angle for the bisecting technique, they found that the paralleling technique is, in general, more accurate. In this study the results were similar to found by Rushton and Horner[25] and Coelho *et al*.[26]

Table 2: Mean and SD of ABL of different types of radiographic methods (*n*=70)

Radiographic methods	Mean	SD
Control	3.011	1.563
CBCT	3.085	1.350
Digital periapical	2.754	1.426
Periapical with Rinn XCP film holder	2.739	1.390
Panoramic	2.664	1.323
Periapical with Han-Shin film holder	2.244	1.335

SD: Standard deviation; ABL: Alveolar bone loss; CBCT: Cone-beam computed tomography

Different from Persson *et al*.[14] and Langlois Cde *et al*.[27] who found that periapical radiographs and panoramic images showed similar accuracy, in the present study panoramic radiographs (mean 2.664) were more accurate to detect ABL than periapical using Han-Shin film holder (mean 2.224). However, compared with the control results the panoramic images were close, so indicating the panoramic as an initial test for the evaluation of ABL. In this respect, the authors[14,27] agree with results of this research.

In this manuscript, CBCT showed the most accurate ABL measurements, not statistically different from the control method. Similar results were found by Raichur *et al*.,[5] Vandenberghe *et al*.,[28] Grimard *et al*.,[29] and Mol and Balasundaram[3] who compared CBCT images with digital radiography in the detection of intrabony defects. The authors[5,28] used two measurements - from the CEJ to the bottom of the bone defect (CEJ-BD), and CEJ-ABC. They found that both CBCT and digital radiography had similar means for CEJ-ABC, whereas for CEJ-BD digital radiography showed a discrepancy of 1-2 mm from the actual means, with CBCT being more accurate to assess BD.

Mengel *et al*.[30] compared different radiographic methods for accuracy and quality of the representation of BDs. They found more accuracy for CBCT, the images in three plans with no overlapping or distortion. The same result found in the present manuscript.

Similarly, Georgescu *et al*.,[31] CBCT was significantly more accurate than panoramic images in this study. The scholars[31] evaluated CBCT and panoramic radiography, quantitatively and qualitatively, and concluded that CBCT images were more accurate to evaluate anterior mandibular area.

Table 3: Tukey's test for multiple comparisons among different radiographic methods

Tukey's multiple comparisons test	Mean difference	95% CI of difference	*P* value
Rinn XCP versus panoramic	0.07429	−0.3105-0.4590	0.9929
Han-Shin versus panoramic	−0.4200	−0.7363- −0.1037	0.0030*
Digital periapical versus panoramic	0.0900	−0.2363-0.4163	0.9650
CBCT versus panoramic	0.4209	0.05996-0.7818	0.0130*
Control versus panoramic	0.3463	−0.1067-0.7993	0.2329
Han-Shin versus Rinn XCP	−0.4943	−0.8296- −0.1590	0.0007*
Digital periapical versus Rinn XCP	0.01571	−0.3033-0.3347	>0.9999
CBCT versus Rinn XCP	0.3466	0.06785-0.6253	0.0066*
Control versus Rinn XCP	0.2720	−0.05810-0.6021	0.1653
Digital periapical versus Han-Shin	0.5100	0.1788-0.8412	0.0004*
CBCT versus Han-Shin	0.8409	0.5053-1.176	<0.0001*
Control versus Han-Shin	0.7663	0.3844-1.148	<0.0001*
CBCT versus digital periapical	0.3309	0.08380-0.5779	0.0027*
Control versus digital periapical	0.2563	−0.1418-0.6544	0.4188
Control versus CBCT	0.07457	−0.3691-0.2200	0.9759

*P<0.05 statistical significance\s. CI: Confidence interval; CBCT: Cone-beam computed tomography

The comparison between CBCT with periapical radiographs showed, again, that CBCT is more accurate in detecting and locating ABL, as de Faria Vasconcelos *et al*.[32] also found. In contrast, Misch *et al*.,[33] who used CBCT, periapical radiography, periodontal probe, and an electronic calliper as the standard reference, found no difference between CBCT and periapical images in the detection of interproximal BDs. However, Misch *et al*.[33] also found that CBCT, but not periapical radiography, was able to detect buccal and lingual defects. As conventional radiography cannot assess the buccal and lingual surfaces, the present study opted to measure the interproximal surfaces, which allows the comparison among different radiographic methods.

Given the present research, it is clear that for interproximal BDs CBCT is not necessary given the fact that other techniques provide satisfactory accuracy except conventional periapical radiography using Han-Shin film holder.

Conclusion

Within the limitations of this study, compared with the control measurements, only conventional periapical radiography using Han-Shin film holder showed significant lower differences, whereas the values of CBCT were the closest to the control method.

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