Interpretation of chemically created periapical lesions using 2 different dental cone-beam computerized tomography units, an intraoral digital sensor, and conventional film

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Objective. To assess the diagnostic potential of 2 different cone-beam computerized tomography (CT) units and compare this with intraoral digital and conventional film in the detection of chemically created periapical lesions.
Study design. Periapical lesions were created chemically in 27 intact roots of 23 teeth (6 incisors, 4 canines, 6 premolars, and 7 molars). Cone-beam CT and digital and film images of the teeth were obtained before and after the lesions were created. Three observers separately used a 5-point scale to rate the images for the presence or absence of periapical pathology. Images were scored twice by each observer, with an interval of 4 weeks. Kappa values were calculated to assess intra- and interobserver agreement. Data were analyzed using repeated-measures analysis of variance for nested designs. R^2 values were used to assess the models for each observer for each method. Differences between observers and methods were tested for statistical significance with the paired *t* test.
Results. Kappa coefficients for intraobserver agreement ranged from 0.196 to 0.542 for the 2-dimensional (2D) images and from 0.533 to 0.699 for the cone-beam CT images, whereas kappa coefficients for interobserver agreement ranged from 0.223 to 0.302 for the 2D images and from 0.417 to 0.461 for the cone-beam CT images. The R^2 values for each observer showed that cone-beam CT images were superior to 2D intraoral images. There was no difference between the 2 cone-beam CT units tested ($P > .05$), and no difference was found between the 2 intraoral radiographic techniques tested ($P > .05$).
Conclusion. The 2 cone-beam CT units tested performed similarly, and both performed better than intraoral digital and film radiography in detecting chemically created periapical lesions. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:426-432)**

Diagnosis of periapical pathology is of paramount importance in enabling the clinician to provide immediate and appropriate dental treatment.[1] Both 2-dimensional (2D) intraoral digital radiography and film radiography are used to detect periapical pathology[2,3]; however, both methods provide limited information regarding the origin, size, and location of periapical lesions.[4,5] Especially when the background pattern is complex, adjacent anatomic and dental structures can interfere with the detection of periapical lesions, and this requires the clinician to take several radiographs from different angulations.[6] When not discovered through conventional imaging, periapical lesions may eventually lead to complications, making it essential to find more effective and accurate methods to diagnose periapical pathology.

Currently, radiography is still the only means available for diagnosing periapical pathology in routine clinical practice. The recent introduction of cone-beam computerized tomography (CT), which is uniquely designed for dentomaxillofacial imaging, has enabled 3-dimensional (3D) visualization of teeth and can be used in endodontics, periodontics, and orthodontics as well as in dentomaxillofacial surgery.[7,8] Cone-beam CT uses a cone-shaped X-ray beam centered on a 2D sensor to scan a 180°-360° rotation around the patient's head to acquire a full 3D volume of data.[9-11] The use of cone-beam CT in clinical practice can provide a number of potential advantages over conventional tomography, such as easier image acquisition, higher image accuracy, reduced artifacts, lower effective radiation doses, faster scan times, and greater cost-effectiveness.[11-13]

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The aim of the present study was to assess and compare the diagnostic potential of 2 different cone-beam CT units, intraoral digital radiographs, and conventional film radiographs in the detection of chemically created periapical lesions.

MATERIAL AND METHODS

This study was conducted using 3 fresh cadaver mandibles from people who gave informed consent to donate their bodies for medical research and teaching. After the removal of soft tissue and preliminary radiographic examination, 27 intact roots of 23 teeth (6 incisors, 4 canines, 6 premolars, and 7 molars) were selected.

Periapical lesions were created as described in an earlier study[14] by extracting each tooth with minimal force, placing a cotton pellet at the apex of the tooth socket, saturating the pellet with 0.10 mL 70% perchloric acid for 6–12 h, capping the socket with a small vinyl polysiloxane plug, and cleaning the socket with a cotton pellet and distilled water.

Intraoral digital, conventional film, and cone-beam CT images were obtained both before and after the creation of the lesions. Intraoral digital and conventional images were exposed with a Trophy Trex X-ray unit (Croissy, Beaubourg, France) operated at 65 kVp and 8 mA with a standardized parallel technique and a focus–receptor distance of 20 cm. Digital images were obtained using a direct digital intraoral charge-coupled device (CCD) sensor, Progeny Vision DX, size 1 (Progeny Dental, Buffalo Grove, IL), with an image exposure time of 0.2 s. The Progeny CCD offers 1.25 million pixels, a pixel size of 22 μm × 22 μm and a theoretical resolution of 23 lines/mm (Fig. 1). Conventional film images were obtained using Primax RDX-58E (Primax, Berlin, Germany) E-Speed size 2 film with an image exposure time of 0.4 s. Films were automatically processed on the same day with a Velopex Extra-X machine (Medivance Instruments, London, England) and fresh chemicals in accordance with the manufacturer's instructions. For both digital and conventional radiographs, the visibilities of the pulpal root canal, dentin, periodontal ligament, and trabecular pattern of the bone were used to indicate optimal image quality. The cone-beam CT images were obtained using a Next Generation i-CAT (Imaging Sciences International, Hatfield, PA) with a 20 × 25 cm flat-panel sensor and an Iluma ultra cone-beam CT scanner (Imtec Imaging, Ardmore, OK) with a 24.4 × 19.5 cm amorphous silicon flat-panel image detector and a cylindrical volume of reconstruction up to 21.1 × 14.2 cm. With the i-CAT system, images were obtained at 120 kVp, 5 mA, and 0.125 mm voxel size, with an exposure time of 17.5 s. With the Iluma system, images were obtained at 120 kVp, 3.8 mA, and an ultrahigh voxel size of 0.09 mm, with an exposure time of 40 s. For both CT units, the smallest voxel sizes were selected to assess the systems' maximum detection capabilities. Volumetric data were reconstructed to provide serial coronal and sagittal sections for both cone-beam CT systems. Cross-sectional images obtained with the i-CAT and Iluma are shown in Figs. 2 and 3, respectively.)

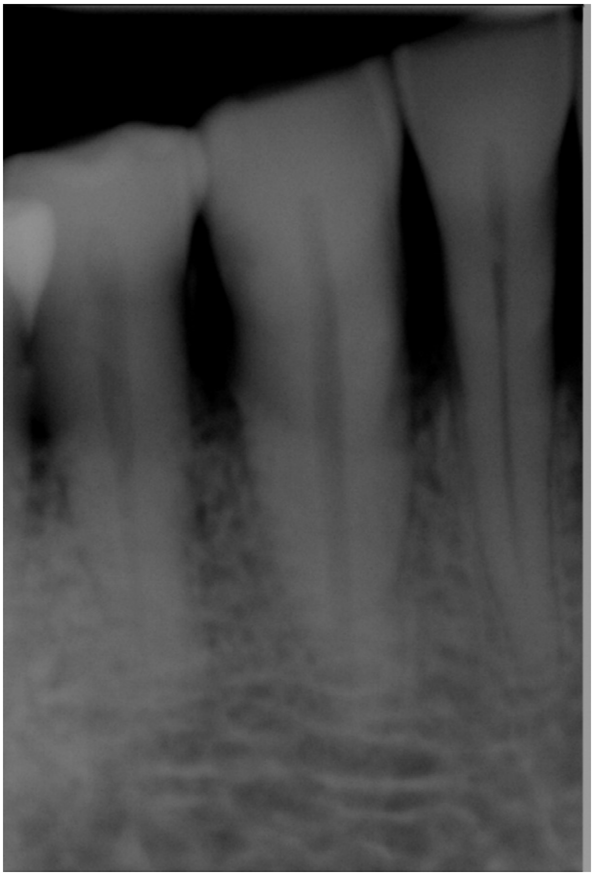

Fig. 1. Intraoral periapical radiography obtained by Progeny CCD sensor.

All intraoral digital and conventional radiographs and cone-beam CT images were evaluated separately by 3 observers experienced in image interpretation. Viewing was conducted in a room with dimmed light. The presence or absence of periapical pathology (periapical radiolucency, widened periodontal ligament space, and loss of lamina dura) was scored using the following 5-point scale: 1 = lesion definitely present; 2 = lesion probably present; 3 = uncertain, unable to tell; 4 = lesion probably not present; and 5 = lesion definitely not present. No time restriction was placed on the observers. Conventional radiographs were coded and evaluated at random with a light box, and observers were permitted to use a ×2 magnifying glass, as necessary. Digital intraoral images and selected cross-sec-

Fig. 2. Cross-sectional image obtained by i-CAT system. Exposures were taken at 120 kVp, 5 mA, and an exposure time of 17.5 s with 0.125 mm voxel size.

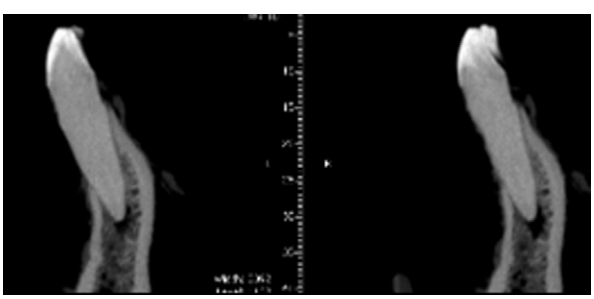

Fig. 3. Cross-sectional images obtained by Iluma unit. Exposures were taken at 120 kVp, 3.8 mA, and an exposure time of 40 s with ultrahigh voxel size (0.09 mm).

tional and coronal cone-beam CT images were adjusted and exported to Microsoft Powerpoint to create 3 separate files for each of the 3 image acquisition methods. Images were coded and evaluated at random on a computer monitor (15" Toshiba Satellite) with a screen resolution of 1024 × 768 pixels and 32-bit color depth. Intraobserver agreement was assessed by having each observer view all images twice, with a 4-week interval between viewings to eliminate memory bias.

Kappa values were calculated to assess intra- and interobserver agreement. Data were analyzed using repeated-measures analysis of variance for nested designs with PROC GLM in SAS 9.0. The 5-point rating score was the dependent variable. The presence or absence of a lesion was the between-subject factor, with the between-subject variability being indicated by specimen being nested within the presence or absence of a lesion. R^2 values were used to assess the models for each observer for each method. The paired-sample *t* test for 2 proportions was used to test for significant differences between observers and methods.

Table I. Kappa values for intraobserver agreement and inter-observer agreement

	Image type			
	CCD	*Film*	*i-CAT*	*Iluma*
Intraobserver agreement				
Observer 1	0.290	0.196	0.627	0.699
Observer 2	0.386	0.422	0.544	0.553
Observer 3	0.542	0.352	0.575	0.659
Interobserver agreement				
First reading	0.240	0.223	0.461	0.425
Second reading	0.224	0.302	0.448	0.417

RESULTS

Kappa values for intraobserver agreement ranged from 0.196 to 0.542 for the 2D images and from 0.533 to 0.699 for the cone-beam CT images, whereas kappa values for interobserver agreement ranged from 0.223 to 0.302 for the 2D images and from 0.417 to 0.461 for the cone-beam CT units, indicating relatively better agreement for the cone-beam CT units. Table I shows the kappa values for intra- and interobserver agreement.

The R^2 values of all 12 assessments (3 observers × 4 imaging methods) obtained by observers 1, 2, and 3 are presented in Tables II, III, and IV, respectively. The R^2 values for observer 1 were as follows: film 0.413, CCD 0.462, i-CAT 0.825, Iluma 0.732. The R^2 values for observer 2 were: film 0.536, CCD 0.393, i-CAT 0.740, Iluma 0.747. The R^2 values for observer 3 were: film 0.487, CCD 0.584, i-CAT 0.773, Iluma 0.835.

There was no statistically significant difference between the 2 cone-beam CT units tested ($P > .05$), and no statistically significant difference was found between the 2 intraoral radiographic techniques tested ($P > .05$). Both cone-beam CT units outperformed both digital and conventional radiographs for all observers; however, for the second observer film and i-CAT/Iluma comparisons and for the third observer CCD and i-CAT comparison were not statistically significant ($P > .05$).

DISCUSSION

The diagnosis of periapical pathology with 2D digital and conventional film radiographs is affected by a

Table II. Summary of results of 2-factor nested repeated-measures analysis of variance for observer 1

Effect	*df*	*SS*	*F*	*P*	R^2	
Film	Presence or absence of lesion	1	31.935	20.29	<.0001	
	Specimen nested within presence or absence of lesion	4	19.042	3.02	.0265	
	Model	5	53.283	6.77	<.0001	0.413
	Error	48	75.550			
Progeny (CCD)	Presence or absence of lesion	1	20.641	14.02	.0005	
	Specimen nested within presence or absence of lesion	4	38.088	6.47	.0003	
	Model	5	60.773	8.26	<.0001	0.462
	Error	48	70.653			
i-CAT	Presence or absence of lesion	1	129.973	220.73	<.0001	
	Specimen nested within presence or absence of lesion	4	3.069	1.30	.2822	
	Model	5	133.736	45.42	<.0001	0.825
	Error	48	28.264			
Iluma	Presence or absence of lesion	1	97.802	114.35	<.0001	
	Specimen nested within presence or absence of lesion	4	10.873	3.18	.0214	
	Model	5	112.280	26.26	<.0001	0.732
	Error	48	41.053			

Statistically significant differences were demonstrated between 5-point rating-scale scores for film and i-CAT ($P < .01$), for film and Iluma ($P < .05$), for CCD and i-CAT ($P < .01$), and for CCD and Iluma ($P < .05$).

Table III. Summary of results of 2-factor nested repeated-measures analysis of variance for observer 2

	Effect	*df*	*SS*	*F*	*P*	R^2
Film	Presence or absence of lesion	1	43.244	28.51	<.0001	
	Specimen nested within presence or absence of lesion	4	37.921	6.25	.0004	
	Model	5	84.217	11.10	<.0001	0.536
	Error	48	72.819			
Progeny (CCD)	Presence or absence of lesion	1	29.827	16.16	.0002	
	Specimen nested within presence or absence of lesion	4	23.246	3.15	.0223	
	Model	5	57.487	6.23	.0002	0.393
	Error	48	88.605			
i-CAT	Presence or absence of lesion	1	109.242	122.24	<.0001	
	Specimen nested within presence or absence of lesion	4	9.695	2.71	.0408	
	Model	5	122.362	27.38	<.0001	0.740
	Error	48	42.897			
Iluma	Presence or absence of lesion	1	102.550	129.77	<.0001	
	Specimen nested within presence or absence of lesion	4	7.773	2.46	.0579	
	Model	5	111.940	28.33	<.0001	0.747
	Error	48	37.930			

Statistically significant differences were demonstrated between 5-point rating-scale scores for CCD and i-CAT ($P < .01$) and for CCD and Iluma ($P < .01$).

number of variables related to these imaging methods. These variables include angulation of the central beam, exposure time, receptor sensitivity, processing, viewing conditions, observer experience and the superimposition of anatomic structures, as well as lesion location and the position of the tooth in the jaw. Cone-beam CT is a new and versatile tool for the diagnosing, differentiating, treatment planning, and monitoring of periapical lesions. Cone-beam CT can provide more accurate information about the sizes and locations of periapical lesions than 2D techniques, without their limitations.

To our knowledge, there is no published study that uses different cone-beam CT units in the detection of periapical lesions. The results of the present study found that both the i-CAT and Iluma cone-beam CT units perform better in the detection of chemically created periapical lesions compared with 2D intraoral techniques. No statistically significant difference was found between the 2 cone-beam CT units tested, and no difference was found between intraoral digital and conventional radiography. We acknowledge that our 27 specimens were obtained from only 3 cadavers and are not independent, but to obtain 27 specimens from 27 cadavers was neither practical nor possible for us to do.

To assess the maximum detection ability of the cone-beam CT units, the smallest voxel size offered by each

Table IV. Summary of results of 2-factor nested repeated-measures analysis of variance for observer 3

	Effect	*df*	*SS*	*F*	*P*	R^2
Film	Presence or absence of lesion	1	31.859	30.18	<.0001	
	Specimen nested within presence or absence of lesion	4	13.920	3.30	.0182	
	Model	5	48.161	9.12	<.0001	0.487
	Error	48	50.672			
Progeny (CCD)	Presence or absence of lesion	1	41.220	36.48	<.0001	
	Specimen nested within presence or absence of lesion	4	31.843	7.05	.0002	
	Model	5	76.306	13.51	<.0001	0.584
	Error	48	54.230			
i-CAT	Presence or absence of lesion	1	101.181	151.52	<.0001	
	Specimen nested within presence or absence of lesion	4	4.762	1.78	.1477	
	Model	5	108.929	32.62	<.0001	0.773
	Error	48	32.052			
Iluma	Presence or absence of lesion	1	117.392	223.95	<.0001	
	Specimen nested within presence or absence of lesion	4	5.876	2.80	.0360	
	Model	5	127.376	48.60	<.0001	0.835
	Error	48	25.161			

Statistically significant differences were demonstrated between 5-point rating-scale scores for film and i-CAT ($P < .05$), for film and Iluma ($P < .01$), and for CCD and Iluma ($P < .05$).

unit was selected. To better simulate actual lesions, perchloric acid was applied to tooth sockets to chemically create perapical lesions. Chemically created lesions have diffuse borders that are radiographically similar to those of actual biologic lesions, whereas simulated lesions prepared using drills or burs produce high-contrast images with clearly defined borders that are more easily detected. In addition, the chemical technique used in this study allowed demineralization to advance in the same manner as lesions of endodontic origin.[14]

In one previous study,[15] CCD sensor, intraoral film, and cone-beam CT images were compared for accuracy in the detection of bur-created periapical lesions in pig jaws. The results demonstrated that sensitivity, positive predictive value (PPV), and diagnostic accuracy were higher with the Newtom 3G cone-beam CT compared with both Dixi2 digital and conventional intraoral radiographs. Sensitivity was 28.3 for film, 23.3 for CCD, and 54.2 for Newtom 3G; specificity was 76.7 for film, 70.0 for CCD, and 75.0 for Newtom 3G; PPV was 70.5 for film, 60.5 for CCD, and 82.6 for Newtom 3G; negative predictive value (NPV) was 34.9 for film, 31.4 for CCD, and 44.5 for Newtom 3G. Similarly, in the present study, both cone-beam CT units tested outperformed both digital and conventional radiographs in the detection of periapical lesions, whereas there was no statistical difference between the intraoral methods or between the cone-beam CT units.

In a retrospective in vivo study, 42 of 46 lesions (91%) could be detected from cone-beam CT images (3D Accuitomo; J Morita Mfg Corp, Kyoto, Japan) compared with only 32 of 46 (70%) from 2D digital and conventional film images.[16] Moreover, observers agreed that in these 32 cases, the Accuitomo images provided clinically relevant information not found in the periapical radiographs. This information included better, more accurate visualization of root and root canal anatomy, lesion location, particularly the relation of the lesion to the maxillary sinus, and lesion size.[16]

In line with our findings, other studies found no difference between digital and conventional radiographic images when used in the diagnosis of periapical lesions. Both D-speed and E-speed film images have been found to be similar to direct digital images for the detection of simulated periapical lesions.[16,17] Radiographs and grayscale digital images were found to be similar, whereas color and reverse images were associated with a greater spread of diagnostic scores.[18] In a study that compared film, direct digital, and radiographic images that were transmitted by telephone, no statistically significant difference was found between image type in the ability of the evaluator to identify artificial periapical bone lesions.[19] Conventional film and photostimulable phosphor plates (PSPs) (Digora; Soredex) have also been shown to be equivalent imaging modalities regarding the detection of pathologic periradicular bone loss in cadavers.[20] Another study has demonstrated that complementary metal oxide semiconductor (CMOS) systems yield similar results to film and CCD; however, CMOS digital systems use less energy and may have longer life spans than CCD sensors. In all cases, lesion detection occurred with greater accuracy in cortical bone than in trabecular bone.[21] In a study of Schick CDR and Trophy direct-digital radiographic systems, no significant difference was found in the accuracy of detecting artificially prepared lesions between image systems, and there was a highly significant level of agreement between examiners ($P < .01$).[22]

In contrast to these findings, some studies have found differences in the diagnosis of periapical lesions using intraoral digital images compared with conventional film radiographs. In one study, conventional radiographs performed better than Radiovisiography (RVG) when no lesion existed, whereas RVG was superior in diagnosing enlarged lesions involving the lamina dura and medullary bone; however, no difference was found between conventional radiography and RVG when the lesion involved cortical bone.[23] In another study, in which periapical lesions were chemically created by applying 70% perchloric acid solution at different time intervals between 12 and 24 h, lesions were diagnosed significantly better using digital imaging than conventional radiography; however, no significant difference was found between digital imaging and conventional radiography when no lesion existed or at 36 h and thereafter. Moreover, variations in enhancement settings did not affect the diagnosis at any of the times tested.[24] In the present study, perchloric acid was applied for only 6–12 h to avoid creating very large lesions that might invalidate the study results.

In another study, histogram equalization and linear and pseudocolor enhancement of images yielded a statistically significant improvement over reverse-contrast images at different time intervals of perchloric acid application.[14] Similar to the findings of the present study, intraobserver reproducibility showed moderate agreement, but interobserver agreement was only fair. Another study found slightly better results for conventional film compared with direct digital radiography in the detection of periapical bone lesions, and image processing was not found to improve observer performance.[25] In a study with lesions created using burs of increasing diameter, RVG using variable contrast was more accurate than film in detecting the smallest lesions, but there was no difference between RVG and film with lesions of other sizes.[26] In another study in which observers could manipulate image characteristics, Ektaspeed Plus film outperformed both CCD and PSP images in the detection of simulated periapical lesions. Intraobserver agreement in that study was only fair.[27] Image processing of high-quality direct digital images was found to have only a limited effect on diagnostic accuracy, with adjustments of contrast and brightness resulting in the largest improvements.[28] Not only are digital system enhancement tools task specific, their efficacy depends on observer experience, which makes them subjective diagnostic tools. In the present study, to speed up the evaluation process, digital intraoral images were enhanced by manipulating contrast and brightness before exporting the images to PowerPoint; therefore, observers did not use the enhancement tools.

Although cone-beam CT is an innovative and promising technology, effective radiation doses are still higher than with conventional panoramic imaging. Radiation doses from cone-beam CT scans vary substantially between devices, fields of view (FOVs), and other technical factors. Compared with the Newtom 3G (Quantitative Radiology, Verona, Italy), radiation doses from full-FOV examinations have been found to be 3.3 times greater using the i-CAT. According to International Commission on Radiological Protection 2005 draft guidelines, the effective radiation dose from a 12" FOV i-CAT (193.4 μSv) is 14.5 times and from a 9" i-CAT (104.5 μSv) 8.6 times higher than that of panoramic radiography (13.3 μSv).[29] In a search of the literature, however, we were unable to find a study concerning the effective radiation doses of the Iluma system.

In the present cadaver study, both cone-beam CT systems were operated at the maximum resolution mode, which is known to impart significantly more dose and requires more reconstruction time than the standard mode. This makes it impossible for cone-beam CT to be used for diagnosing periapical lesion in all cases. We do not suggest that cone-beam CT be used rather than standard intraoral radiography as the method of choice for screening and detecting periapical lesions in routine clinical practice. The aim of this in vitro study was to assess the detection ability of the cone-beam CT units compared with intraoral radiography. Periapical disease may be detected sooner using cone-beam CT compared with periapical views, and the lesions can be assessed in coronal, axial, and sagittal views. Currently, cone-beam CT must only be considered when conventional radiographic techniques are insufficient to provide enough information for the diagnosis of periapical pathology.

It is our belief that the introduction of cone-beam CT units with higher resolution and lower effective doses, along with the development of related software, will help in improving the diagnosis and assessment of periapical disease.

CONCLUSIONS

Two cone-beam CT units performed better than intraoral digital and conventional film radiography in detecting chemically created periapical lesions in vitro. Both intra- and interobserver agreement were higher for the cone-beam CT units compared with both 2D intraoral imaging techniques. There was no difference between the cone-beam CT units when used to detect periapical lesions. Similarly, there was no difference between digital and film radiography when used to detect periapical lesions.

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