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Original Article

Comparison of periapical parallel radiography with cbct with different field of views (FOV) for the detection of periapical lesions

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ABSTRACT

Background: Chronic apical periodontitis (AP) may influence the outcome of root canal treatment. Thus, it is important to diagnose AP using the best method available. This research was done to compare the diagnostic accuracy of parallel periapical radiography (PR) and different field of views (FOVs) of cone-beam computed tomography (CBCT).

Materials and Methods: This *ex vivo* study was done on six human mandibles. After extraction of the teeth, periapical lesions with different sizes were prepared randomly by drilling a hole at the base of the socket using a bur. From among 67 sockets, 21 sockets had no lesion (control); then, all mandibles were scanned by CBCT with different FOVs and paralleling periapical technique radiography. The images were assessed by two examiners. The quantitative data were analyzed by intraclass correlation coefficient (ICC) and the qualitative data were analyzed by McNemar's test ($\alpha = 0.05$). Sensitivity, specificity, and accuracy were calculated. Inter-observer agreement was assessed using kappa statistics for qualitative data and ICC for quantitative data.

Results: The quantitative scores were compared with the gold standard using ICC, which showed maximum agreement for the dental FOV of CBCT (93.3) and minimum agreement for PR (62.5) ($P < 0.001$). For qualitative data, maximum agreement was found for the dental FOV of CBCT (97.1%), and minimum agreement was reported for PR (59.7%). Kappa values were variable between 0.271 and 0.924 ($P < 0.001$). Maximum sensitivity was found for the dental FOV of CBCT (96%) and minimum sensitivity was observed for PR (51%). The inter-observer agreement was 0.922 for qualitative data and 0.90 for quantitative data ($P < 0.001$). There were no significant differences between CBCT with different FOVs and defect sizes (gold standard) while we found significant differences for periapical by defect sizes.

Conclusion: CBCT with dental FOV presents the highest sensitivity and diagnostic accuracy for detection and characterization of simulated AP.

Key Words: Cone-beam computed tomography, periapical periodontitis, radiography

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INTRODUCTION

Chronic apical periodontitis (AP) refers to localized inflammation of periapical tissues. AP results from bacterial infection of the root canal and the surrounding dentin.[1,2] AP may affect the outcome of root canal therapy and fresh socket implant insertion. Therefore, its detection and characterization are important preoperative prognostic factors.[3,4]

The localization, involvement of trabecular and/or cortical bone, and size and amount of bone destruction relative to the jaw dimensions at a specific site of the defect are factors affecting the detection of periapical bone lesions.[5] AP cannot be detected when lesions are enclosed in the cancellous bone or masked by a thick cortex. This is because the overlying cortical plate may conceal the periapical lesion[6,7] unless the bone loss is greater than a threshold or the cortical bone is involved in the process.[8] The cortical plate, which acts as an anatomical noise, is also a reason for the underestimated radiographic size of periapical lesions in comparison with the real size of the periapical lesion.[9] The inability to take parallel radiographs in specific circumstances is another reason that may affect the radiological size of periapical lesions. Geometric distortion may elevate or reduce the lesion size or may even make it impossible to envision it.[1]

Studies have shown that cone-beam computed tomography (CBCT) is more accurate than periapical radiography (PR), thus it can spot a greater number of APs than conventional radiography.[4,10] Moreover, the reproducibility of the radiographs becomes crucial when it is necessary to monitor the progress and amelioration of endodontic lesions. Standardization of the images helps to detect the lesions easily and to visualize any alterations in the periapical tissues. Visualization, however, appears to be more effortlessly accomplished with CBCT than with conventional radiology.[11] CBCT systems vary in characteristics such as field of view (FOV), voxel size, and image detection system. FOV refers to the scan volume of a specific CBCT unit. FOV is calculated by the detector size and shape, beam projection geometry, and beam collimation. It can be adjusted in height and width to restrict radiation exposure to merely the intended area.[12] Large-volume CBCT scanners can record the whole maxillofacial skeleton or the entire maxilla or mandible. However, CBCT scanners with limited FOV can record small regions equivalent to 3–5 teeth. It has been argued that the large-volume scanners generate grainier images than the small ones because of both higher amounts of noise from the scattered radiation. Limited scanners are better for managing endodontic problems.[13,14] To pick up the most desirable radiological technique and scan protocol for the detection of periapical lesions, it is essential to evaluate the effect of FOV on diagnostic accuracy. The current study aimed to compare the paralleling periapical technique with CBCT at different FOVs for the detection of periapical lesions.

MATERIALS AND METHODS

This *ex vivo* study with ethics code IR.MUI.REC.1395.3.439 was conducted on six human mandibles prepared by the Anatomy Department of Isfahan University of Medical Sciences.

Preoperation mandibles evaluation

All mandibles were evaluated by panoramic radiography to detect if there were any existing bone lesions. No lesion was observed, thus no mandibles were excluded.

Bone lesion preparation

Six dry human mandibles which were donated to the Anatomy Department of Isfahan University of Medical Sciences were included in this experimental study. Each mandible was immersed in warm water for 90 min. The existing teeth were extracted, and a standard bone lesion was drilled in the alveolar socket in the periapical region using a dental laboratory bur (Brasseler, Savannah, GA, USA) in a laboratory handpiece. The lesions were created at the end of the sockets and parallel to the long axis of the dental sockets. No rotation was made during drilling. The sizes below were utilized to create artificial bone defects: 1.7, 2.1, 3.4, and 4.2 mm in diameter. These were the diameters of the four different sizes of the burs which were measured by a caliper and were considered the gold standard. A random distribution of the four defect sizes was made at the base of the sockets. In some sockets (controls), no lesion was prepared. Then, the extracted teeth were returned to their sockets. From the total of 67 sockets, 21 had no lesion (control group) and 46 had lesions with different sizes.

Radiographic technique

All mandibles were scanned by CBCT using Galileos Orthophos XG three-dimensional X-ray units (Sirona Dental Systems Inc., Bensheim, Germany) at three different FOVs dental (8 cm × 8 cm × 8 cm), single arch (12 cm × 15 cm × 15 cm), double arch (15 cm × 15 cm × 15 cm). Images were reconstructed by SIDEXIS IX software (Sidexis XG; Sirona, Hessen, Germany). Paralleling periapical technique images were taken by Planmeca X-ray machine (Planmeca, Helsinki, Finland) using Digora (Soredex Corporation, Helsinki, Finland) storage phosphor plates (size 2, active area of 30 mm × 40 mm) and a film holder (Rinn XCP-DS Fit Universal Sensor Holders, Dentsply Sirona, USA) in which the plate was parallel with the area of the mandible and central X-ray was perpendicular to the receptor. The exposure parameters were 63 kV, 8 mA, and 0.125 s for PR and 85 kVp, 13 mA, and 5.1 s for CBCT.

Radiological assessment

Images were assessed by two oral and maxillofacial radiologists. All CBCT images were assessed in three planes (tangential, cross-sectional, and axial). The filters were set to the normal state, and merely brightness and contrast were calibrated. The periapical status was evaluated, and scores 0 and 1 showed the absence and presence of lesions, respectively. Furthermore, the size of the lesions was measured by SIDEXIS IX software (Sidexis XG; Sirona, Hessen, Germany). These measurements were done on the periapical images using Scanora 5.0 software (Digora, Helsinki, Finland).

Statistical analysis

Statistical analysis was done by SPSS software (version 22, IBM, NY, USA). The quantitative data were compared with the gold standard for apical lesions (actual size of the lesions) using the intraclass correlation coefficient (ICC), and the qualitative data were analyzed using McNemar's test. Sensitivity, specificity, and accuracy were computed based on the total number of lesions detected. Inter-observer agreement was evaluated by kappa statistics for the qualitative data and ICC for the quantitative data. A significance level of <5% was considered for all statistical tests.

RESULTS

According to the ICC values, the inter-observer correlation was 0.85 for radiographic measurements and 0.922 for qualitative data according to kappa coefficient ($P < 0.001$).

Table 1 shows that, compared to the gold standard (size of defect), the highest percentage of agreement was found for CBCT with dental FOV (97.1%), while the lowest was reported for periapical radiography (59.7%). The agreement rates for CBCT with single-arch FOV and double-arch FOV were 93.5% and 90.5%, respectively.

Table 2 In a recent study, the highest sensitivity was observed for cone beam computed tomography (CBCT) when using a dental field of view (FOV), achieving an impressive 96%. This was followed by single-arch FOV at 92% and double-arch FOV at 88%. In contrast, periapical radiography (PR) displayed the lowest sensitivity at 50.9%. Notably, all methods demonstrated a perfect specificity of 100%.

Table 3 The inter-observer agreement of various imaging methods was evaluated, with a specific focus on the Intraclass Correlation Coefficient (ICC) values for different field-of-view (FOV) settings in Cone Beam Computed Tomography (CBCT). The results indicated that the ICC for CBCT with a dental FOV reached an impressive 93.3%. In contrast, the single-arch FOV displayed a lower agreement at 81.3%, while the double-arch FOV exhibited an ICC of 77.2%. The PR method showed the least agreement among the methods analyzed, with an ICC value of 62.5%.

Table 1: Results of kappa, McNemar, and agreement percentage or accuracy of each radiographic method compared with gold standard

	Kappa		McNemar	Agreement percentage
	Kappa value (%)	*P*		
CBCT with large FOV	0.734	>0.001	>0.001	90.5
CBCT with medium FOV	0.807	>0.001	>0.001	93.5
CBCT with small FOV	0.924	>0.001	0.125	97.1
Periapical	0.271	>0.001	>0.001	59.7

FOV: Field of view; CBCT: Cone-beam computed tomography

Table 2: Sensitivity and specificity of each radiographic method

Parameter	Small FOV	Medium FOV	Large FOV	Periapical
Sensitivity (%)	96	92	88	50.9
Specificity (%)	100	100	100	100

Table 3: Inter-observer correlations between each radiographic method and its gold standard

	CBCT with different FOVs			Periapical
	Small	Medium	Large	
ICC	93.3	81.3	77.2	62.5
P	>0.001	<0.001	<0.001	<0.001

ICC: Intraclass correlation coefficient; FOV: Field of view; CBCT: Cone-beam computed tomography

Table 4: Comparison of radiographic measurement techniques with the gold standard defect sizes

Radiographic measurement techniques	Sizes of defects (Gold standard)			
	1.7 mm	2.1 mm	3.4 mm	4.2 mm
CBCT with different FOVs (mm), mean±SD				
Small	1.91±0.25	2.29±1.02	3.5±0.32	3.49±0.32
P	0.006	0.392	0.272	0.32
Medium	1.8±0.85	2.4±1.01	3.57±0.15	3.55±0.29
P	0.780	0.160	0.141	0.056
Large	1.91±1.25	2.2±1.15	3.31±1.01	3.46±1.01
P	0.005	0.391	0.492	0.357
Periapical	0.74±1.13	0.87±1.5	3.15±1/25	3.15±1.25
*P**	0.001	0.017	0.001	0.455

*One sample *t*-test. FOVs: Fields of view; CBCT: Cone-beam computed tomography; SD: Standard deviation

Table 4 compares the average value of radiographic measurement techniques (CBCT with different FOVs and periapical) by different defect sizes. The study compared measurements of radiographic findings with fixed defect sizes (1.7, 2.1, 3.4, and 4.2) as a gold standard. In defect size of 1.7, there were significant differences for periapical and also CBCT with small, medium, and large FOVs ($P > 0.05$).

Except for the defect size of 4.2, there were significant differences between periapical values and defect sizes (1.7, 2.1, and 3.4) ($P > 0.05$). However, there were no significant differences between CBCT with different FOVs and defect sizes of 2.1, 3.4, and 4.2 ($P > 0.05$). The CBCT with different FOV measurements was closer to the constant values of the defects (gold standard).

DISCUSSION

The findings of the present study showed that the highest diagnostic accuracy and sensitivity were found for CBCT with dental FOV. The specificity was 100% for all methods.

Detection and characterization of AP are important preoperative prognostic factors involved in the outcome of root canal treatment.[3,4] Although PR remains the routine technique for assessment of the periapical status and diagnosis and treatment plan of the teeth, it has restrictions such as anatomical noise, two-dimensional presentations of objects, and geometric distortion.[4,15] CBCT images clinically produce more pertinent information than periapical radiographs owing to eliminating the superimposition of anatomical structures,[16,17] which helps detect the pathological processes taking place in the cancellous bone.[4] The existing AP may affect the result of root canal treatment;[18] therefore, it is necessary to detect AP by an optimal available technique.

Farida Abesi and Golikani[19] conducted a systematic review and meta-analysis of studies examining the performance of CBCT imaging in AP prediction. According to the analyses, the overall pooled sensitivity, specificity, positive predictive value, and negative predictive value were estimated for CBCT and digital radiography. CBCT imaging has excellent diagnostic accuracy in AP prediction. Furthermore, CBCT has better discriminant test performance for AP than digital radiography.

In a review performed by Hilmi *et al*.,[20] assessment of the periapical tissues using periapical radiographs was shown to have a low-to-moderate agreement with the histopathological assessment. CBCT was reported to be more accurate than PR and demonstrated a good agreement with histopathology, especially for nonroot-filled teeth.

Wolf *et al*.[21] compared the simulated apical lesion (SAL) diagnosis potential of digital intraoral radiography (DIR) and CBCT if there is a relationship between the imaging acquisition methods, SALs-depth, and their correct diagnosis likelihood in human mandibular specimens. One thousand and twenty-four SALs were prepared in cancellous and cortical bone with different penetration depths. The SALs-stages were radiographed with CBCT and DIR. Possible SAL findings were analyzed according to a five-point scale. Significantly differences (first 0.935 and second trial 0.960) were found for the CBCT area under the curve when compared with the DIR (first 0.859 and second trial 0.862) findings. SALs of smaller size were earlier detected by CBCT. In SALs without cortical involvement, the probability of detection increased from 90% to 100%. The SALs-depth had the highest detectability influence on cancellous bone lesions, and CBCT SAL detectability was 84.9% higher than with DIR images. The CBCT diagnosis reproducibility was higher than the one of DIR (kappa CBCT: 75.7%–81.4%; DIR: 53.4%–57.1%).

In a study performed by Uraba *et al*.,[22] the overall periapical lesion detection rates of PR and CBCT imaging were 31.5% and 52.2%, respectively ($P < 0.0001$). All CBCT images involved an FOV of 51 mm in height and 56 mm in width at the center of rotation. The ability of CBCT imaging to identify periapical lesions that were not detected by PR was statistically significant for the maxillary incisors/canines ($P < 0.0001$) and maxillary molars ($P < 0.005$).

Kanagasingam *et al*.[23] compared the diagnostic accuracy of PR and CBCT in detecting AP using histopathological findings as a reference standard. Additional parallax views increased the diagnostic accuracy of PR. CBCT had significantly higher diagnostic accuracy in detecting AP compared to PR using human histopathological findings as a reference standard.

Estrela *et al*.[24] assessed the accuracy of imaging methods in the detection of AP from the databases of the recorded images. The overall sensitivity levels of PR and CBCT were 55 and 100, respectively, and the accuracy of PR was 0.70. The kappa values reported for PR and CBCT were 0.89 and 1.00, respectively, which are similar to our results.

In a study performed by Venskutonis *et al*.,[25] CBCT was more accurate than PR in spotting periapical radiolucencies in the teeth that were treated endodontically. Considering CBCT as the gold standard for lesion detection and setting score 1 for sensitivity, specificity, and accuracy, the values found for PR were 0.57, 1, and 0.76, respectively. Moreover, Liang *et al*.[26] evaluated the ability of PR and CBCT to detect and measure the periapical lesions created at the end of the socket in human jaws. As for CBCT, score 1 was reported for sensitivity, specificity, and accuracy, and PR, scores 0.64, 1, and 0.79 were found, respectively. The results of this research are relatively consistent with those of the above-mentioned studies. The lower accuracy of PR compared with CBCT in these clinical surveys and the current research might be because the lesions were only limited to the cancellous bone and were covered by a more concentrated and mineralized cortical plate.[27]

The increased measured areas in tomographic sections compared with PR can be justified by the possible analysis of the CBCT data by particular software. Hence, assessment of the periapical area can be performed from buccal to lingual aspect at 0.2 mm intervals. This is not possible to be carried out by PR where the final radiograph indicates the sum of several structures, including the healthy cortical bone and cancellous bone.[28]

The dimensions of the FOV primarily depend upon the size and shape of the detector, the geometry of beam projection, and the beam collimation. Collimating the primary X-ray beam restricts the radiation exposure to the region of interest (ROI). It is favorable to confine the field size of images to the minimum volume of ROI. Therefore, dental FOV with a limited size is preferable. FOV must be chosen depending on the needs of each patient. This method decreases extra exposure to the patient and generates better radiographs by downsizing the scattered radiation and increasing the signal-to-noise ratio. In other words, the contrast resolution increases in a limited FOV rather than a larger FOV. In addition, by reducing the FOV, smaller pixel size detectors can be used, thereby increasing the spatial resolution and accuracy of the image proportionally.[29,30]

Safi *et al*.[31] assessed the effect of different sizes and FOVs in the diagnosis of simulated external root resorption (ERR) by CBCT. Amounts of sensitivity in 6 cm × 6 cm FOV with a voxel size of 0.2 mm for small, medium, and large cavities were 95.93%, 96.03%, and 97.1%, respectively. Amounts of sensitivity in 12 cm × 8 cm FOV with the same voxel size for small, medium, and large cavities were noted as 94.4%, 96.03%, and 98.5%, respectively. However, the specificity in FOV of 6 cm × 6 cm and FOV of 12 cm × 8 cm was calculated as 93.03% and 90.83%, respectively. Both used FOVs show nearly the same performances in the case of detection of ERR; therefore, a smaller FOV should be preferably used for the detection of ERR to decrease the amount of imposed radiation dose given to patients.

In an *in vitro* research conducted on the mandibles of pigs, Stavropoulos and Wenzel[32] prepared spherical apical lesions with 1 and 2 mm diameters. Sensitivity values were 23.3 and 54.2 and specificity values were 70 and 75 for PR and NewTom 3G CBCT, respectively. Diagnostic accuracy values were 44.4 and 61.1, respectively, which were less than the results of the present study. The difference between studies may be attributed to factors such as type of device, type, and size of detector, size of pixel, and evaluators' decision thresholds.

Using burs to create lesions is an important limitation of the present research because these lesions are distinguished by a well-defined border. *In vivo* PA lesions are not normally distinguished by immaculate and definite edges, properties that enhance the detection of lesions.[20] Further, they do not always manifest as distinct spherical radiolucent outcomes.

Moreover, the artificial production of lesions by burs makes it possible to have better size control, which was a significant feature of the current research.[33]

We suggest that the chemically created lesion better replicates the characteristics of naturally occurring lesions of endodontic origin. This was represented by diffuse borders and an advancing front of demineralization, characteristic of *in vivo* situation. However, the standardization of the size of a chemically induced lesion is open to question.

Although CBCT is better than PR in detecting AP, it has some drawbacks such as high expense, absence of clinical documentation regarding diagnostic accuracy, and a possibly greater radiation dose according to the equipment and FOV utilized.[34] The radiation dose of CBCT is required to be maintained low as much as possible. To decrease the radiation dose by CBCT, it is advised to use a smaller FOV, less projection, and a bigger voxel size.[35] However, these measures may lead to degradation of the final image. Therefore, in clinical settings, radiation dose must be justified based on the image quality.

Further investigations are required to determine the diagnostic validity of different CBCT scanners and the effect of changing the exposure parameters on the detection of periapical lesions.

CONCLUSION

CBCT with dental FOV presents the highest sensitivity and diagnostic accuracy in the detection and characterization of simulated AP.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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