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Research Article

Diagnostic Value of Cone Beam Computed Tomography in Determination of Root Canal Obturation Length versus Digital Radiography

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ABSTRACT:
Cone Beam Computed Tomography (CBCT) was recently introduced to endodontics to overcome the limitations of conventional PA radiography such as superimposition of anatomical structures and geometric distortion. This study aimed to assess the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of digital PA radiography and CBCT for determination of root filling length in comparison with direct measurements made on histological sections as a gold standard.

Materials and methods: 130 single canal extracted human teeth by obturated root canals were enrolled to the study. Digital Periapical (PA) radiography and 3D cone-beam computed tomography (CBCT) were taken of all teeth and the distance between apical limit of root canal obturation (RCO) and radiographic apex was evaluated by measuring tool of the systems. Then a histologic mesiodistal section prepared of each teeth and the real distance between anatomic apex and RCO was evaluated by measuring tool of stereomicroscope. The accuracy of each methods was evaluated by measuring AUC (area under curve). Statistical analysis was performed with SPSS20. The significance level was set at 0.05.

Results: The area under ROC curve of CBCT was 0.866.The specificity is 100 and the sensitivity is 81.8. PPV is %86 and NPV is %100. The AUC in PA technique is 0.71.The specificity is 98.1 and sensitivity is 63.6. PPV is% 88 and NPV is %93.

Conclusion: The sensitivity and specificity of CBCT for determination of root filling length was higher than PA radiography and the diagnostic value of CBCT is better than PA radiography so CBCT can be requested for specific cases as an adjunct to provide further diagnostic information.

Keyword: Digital Periapical Radiography, Root Canal Obturation Length (RCO), CBCT

INTRODUCTION

Adequate length of root filling is an important factor in success of endodontic treatment (1, 2). Periapical (PA) radiography is commonly used in the clinical setting to assess the length and quality of root filling (3-5).PA radiography provides a 2D image of a 3D object. Thus, determination of root canal filling length by PA radiography has limitations. CBCT was recently introduced to endodontics to overcome the limitations of conventional PA radiography such as superimposition of anatomical structures and geometric distortion (6). Selection of apical constriction as the point of termination of root canal cleaning and filling seems logical to minimize the contact of periapical tissues with the root canal filling materials However, apical constriction cannot be recognized on PA radiographs and the anatomic (radiographic) apex is the only measurable point on these radiographs (7, 8). Evidence shows that cleaning and shaping for elimination of microorganisms from the root canal system and proper root filling must be performed to a working length 0-2 mm shorter than the radiographic apex to preserve the periapical tissue health (9, 10). In a previous study, 30.3% of root canal fillings with a working length radiographically confirmed to be suitable were found to be inappropriate by cone beam computed tomography (CBCT) (11). Over-extension and under-extension of root filling can result in endodontic treatment failure(7, 8, 12, 13). Under-extension leaves a space suitable for colonization and proliferation of microorganisms while over-extension results in stimulation of periapical tissues (7, 13), postoperative pain (14) and development of foreign body reaction in the area (15).

The advent of CBCT has made it possible to visualize the dentition, the maxillofacial skeleton, and the relationship of anatomic structures in three dimensions. CBCT, as with any technology, has known limitations, including a possible higher radiation dose to the patient. Other limitations include potential for artifact generation, high levels of scatter and noise and variations in dose distribution within a volume of interest(16). Beam hardening is a limitation of CBCT, which can cause distortionof image of metal structures and decrease the diagnostic value of images. It has been stated that contrast resolution and spatial resolution of CBCT scans are lower than those of intraoral radiographs. Moreover, the patient radiation dose in this imaging modality is higher than that of intraoral radiography (17).

CBCT should be used only when the patient's history and a clinical examination demonstrate that thebenefits to the patient outweigh the potential risks. CBCT should not be used routinely for endodonticdiagnosis or for screening purposes in the absence of clinical signs and symptoms. Clinicians shoulduse CBCT only when the need for imaging cannot be met by lower-dose two-dimensional radiography(16).The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of digital PA radiography and CBCT for determination of root filling length have not been evaluated since no gold standard is available for this purpose(8). By having a gold standard,the diagnostic value of the two radiographic modalities for determination of root filling length can be calculated. If the higher diagnostic value of CBCTisconfirmed, further assessments with CBCT can be performed for patients with apparently successful root filling based on digital radiographyand clinical symptoms showing a refractory endodontic lesion.

This study aimed to assess the sensitivity, specificity, PPV and NPV of digital PA radiography and CBCT for determination of root filling length in comparison with direct measurements made on histological sections under a stereomicroscope. Finally predictive value of both PA radiography and CBCT will be evaluated by ROC curve.

MATERIALS AND METHODS

Sample size was calculated to be 130 teeth based on the results of our pilot study considering alpha=0.05 and 5% difference in diagnostic value. This study was conducted on 130endodontically treated single-canal human teeth.130 freshly extracted human teeth without calcified canals and dental anomalies were selected. The teeth were immersed in 10% formalin and then cleaned with scalers to remove organic debris and deposits. All teeth were kept in 5.25% sodium hypo-chlorite for 2 hours and then stored in sterile 0.9% saline solution untilthey were used(18). Thereafter, all the teeth were numbered.The root canals had been filled with lateral compaction technique using gutta-percha and AH Plus sealer before inclusion in this study(19). The teeth were mounted in gypsum blocks (0.5 cm) to mask the root apex during radiographic measurement of root length. Also, 0.5 cm distance was maintained between the tooth and intraoral digital sensor to simulate the clinical setting.

Digital PA radiographs were obtained using the parallel technique and Phillips dental X ray unit (Ortholix-Netherlands65 S-Italy) with the exposure settings of 65 kVp, 7.5 mA and 0.32 s radiation time using a CCD digital sensor (RVG 5100; Kodak, England). The study was conducted in the Oral and Maxillofacial Radiology Department of Tabriz University, School of Dentistry. The images were viewed at x4 magnification by Kodak software on a 17-inch, 32-bit and 256 color desktop cathode ray tube monitor (Hansol;720EP Iran) in a slightly lit room without natural light. Two observers, including a postgraduate student of oral and maxillofacial radiology and an oral and maxillofacial radiologist, separately observed the images and measured the distance between the radiographic apex and the apical end of root filling. Extrusion of root filling material through the radiographic apex was recorded as over-extension, 0-2 mm distance between the root filling and radiographic apex was referred to as normal filling and distance more than 2 mm was recorded as under-extended. The observers were allowed to use enhancement filters or change the contrast using brightness/contrast feature of the software. CBCT scans were obtained of teeth using New TomVGi CBCT unit (QR RST, Verona, Italy). The device had 1920x1536 pixel flat panel detector, 360° rotation, 0.127 mm voxel size and maximum of 120 kVp. The scanning conditions were 110 kVp, 4.71 mA and 3.6 s time. Primary and final image reconstructions were performed using NNT Viewer software version 2.21 (Image Work, NY, USA). The images were observed on a 17-inch, 32-bit and 256 color desktop cathode ray tube monitor (Hansol; 720EP Iran) with 1024x768 pixel resolution in a slightly lit room without natural light. The scanned images were sectioned in three spatial planes of coronal, axial and sagittal with 0.3 mm slice thickness and were separately evaluated by the aforementioned two observers. Measurements were made by the software. Assessment of the axial view by changing the plane apicocoronally yielded the best results. Extrusion of root filling material through the radiographic apex in more than one plane was recorded as over-extension, 0-2 mm distance between the root filling and radiographic apex in more than two planes was referred to as normal filling and distance more than 2 mm in more than one plane was recorded as under-extended . It should be noted that a two-week interval was considered between these measurements and the previous ones (PA radiography assessments). Since the coefficient of agreement between the two observers was found to be 0.8, the radiologist was chosen as the final observer. The teeth were then sectioned by a metal disc in mesiodistal direction. Cases with apical fracture or separation of gutta-percha from the canal wall during sectioning were excluded and replaced with new teeth. Sectioned teeth were inspected under a stereomicroscope (IBss2; Nikon, Japan). The actual distance between the root filling and anatomic apex was measured at x20 magnification separately by an operative dentist and a dentistry student. The inter-observer agreement was found to be 0.88. Thus, the results of operative dentist were subjected to statistical analyses.

Descriptive statistics (mean and standard deviation) were calculated and receiveroperating characteristic (ROC) curve was used to determine the diagnostic value of CBCT and PA radiography. The area under the curve known as Azwas also calculated. Sensitivity, specificity, accuracy, PPV and NPV were calculated. Statistical analyses were performed using SPSS version 20.

RESULTS

The inter-observer agreement was calculated using the kappa coefficient (kappa=0.83).

Since the methodology of our study was in accord with that of Li-Cheng et al, the normal values (0-2 mm distancebetween the radiographic apex and the root filling) were divided into four 0.5 mm scales according to their study (11).

Table1. Frequency of root filling length detection by the three methods

		Method			Total
		CBCT	PA radiography	Gold standard	
Normal	0-0.5	28(21.54)	27(20.77)	19(14.62)	74(18.97)
	0.5-1	45(34.62)	48(36.92)	42(32.31)	135(34.62)
	1-1.5	30(23.08)	32(24.62)	37(28.46)	99(25.38)
	1.5-2	9(6.92)	9(6.92)	10(7.69)	26(6.7)
Under-extended		8(6.15)	7(5.4)	9(6.92)	24(6.2)
Over-extended		10(7.69)	7(5.4)	13(10)	32(8.21)
Total		130(100)	130(100)	130(100)	390(100)

Table2. Frequency of diagnostic range of teeth with normal length of root filling based on the gold standard and PA radiography

		Gold standard					
	Row Labels	0-0.5	0.5-1	1-1.5	1.5-2	Grand Total	
PA	0-0.5 (27)	14(51.80%)	8(29.60%)	1(3.70%)	0(0.00%)	23(85.18%)	
	0.5-1 (48)	5(10.41%)	32(66.60%)	10(20.80%)	1(2.08%)	48(100.00%)	
	1-1.5 (32)	0(0.00%)	2(6.25%)	25(78.12%)	4(12.5%)	31(96.87%)	
	1.5-2 (9)	0(0.00%)	0(0.00%)	1(11.11%)	5(55.55%)	6(66.66%)	
	Grand Total	19	42	37	10	108	

Table2 shows that Of 116 teeth which were detected to be normally filled on PA radiographs, 108 were also detected to be normally filled by the gold standard histological assessment. In other words, the agreement between PA radiography and gold standard histological assessment results was 93%.

when distance between the radiographic apex and root filling on PA radiographs was 0.5-1 mm on PA radiographs, there was a high likelihood that the root filling length is actually normal (0-2 mm distance). The lowest accuracy of PA radiography is when the distance is 1.5 to 2 mm since the gold standard assessment showed that in only half of these cases this length was actually normal.

Table3. Frequency of diagnostic range of teeth with normal length of root filling based on the gold standard and PA radiography

		Gold standard				
	Row Labels	0-0.5	0.5-1	1-1.5	1.5-2	Grand Total
CBCT	0-0.5(28)	18(64.28%)	7(25.00%)	0(0.00%)	0(0.00%)	25(89.28%)
	0.5-1(45)	1(2.22%)	35(77.78%)	9(20.00%)	0(0.00%)	45(100.00%)
	1-1.5(30)	0(0.00%)	0(0.00%)	28(93.33%)	2(6.67%)	30(100.00%)
	1.5-2(9)	0(0.00%)	0(0.00%)	0(0.00%)	8(100.00%)	8(88.89%)
	Grand Total	19	42	37	10	108

Table3 shows that Of 112 teeth which were detected to be normally filled on CBCTradiographs, 108 were also detected to be normally filled by the gold standard histological assessment. In other words, the agreement between CBCT radiography and gold standard histological assessment results was 96.5 %.

when distance between the radiographic apex and root filling on PA radiographs was 0.5-1.5mm on CBCT radiographs, there was a high likelihood that the root filling length is actually normal (0-2 mm distance).

Comparison of the results of gold standard histological assessment with CBCT and digital PA radiography:

Table4. Comparison of the detection of root filling length by the gold standard method, CBCT and digital PA radiography

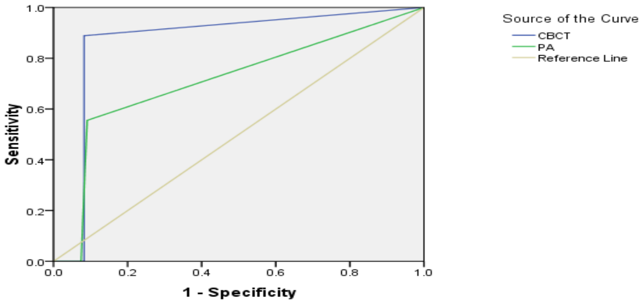
*One-way ANOVA

	Number	Mean	Standard deviation	Minimum	Maximum	F	P value*
CBCT	120	.968	.423	.10	2.30		
PA	121	.981	.532	.10	2.50	.186	.830
Gold standard	117	1.0104	.546	.10	2.35		

The mean distance measured on CBCT scans was 0.968 mm short of the radiographic apex. This value was 0.981 mm on PA radiographs and 1.01 mm by histological measurement. ANOVA found no significant difference among the three methods (P>0.05).

The ROC curve was used for comparison of *Diagnostic value of CBCT and PA radiography to the gold standard* (Graph 1). The area under the curve was 0.866 for CBCT (95% CI:0.74-0.98). The cutoff point of 2 showed the highest balance between sensitivity and specificity. At this point, the sensitivity was 81.8% and the specificity was 100%. The PPV was 86%, the NPV was 100% and the accuracy was 95.8%.

The area under the curve was 0.71 for PA radiography (95% CI: 0.517-0.906). The sensitivity was 63.6% and the specificity was 98.1%. The PPV was 88% and the NPV was 93%. The accuracy was 97.1% (Tables 5 and 6).



Graph1. ROC curve

Table5. Area under the ROC curve in CBCT and PA radiography

Method	Area	P value	95% CI	
			Lower level	Upper level
CBCT	.866	.000	.746	.987
PA radiography	.712	.035	.517	.906

Table 6. Sensitivity, specificity, PPV and NPV of CBCT and PA radiography

Method	Sensitivity	Specificity	PPV	NPV	Accuracy
CBCT	95.8	100	86	100	81.8
PA radiography	97.1	93	88	98.1	63.6

DISCUSSION

Statistically, specificity is the most important parameter used for the comparison of diagnostic value of two methods. CBCT had higher sensitivity and specificity than PA radiography in our study and the area under the ROC curve showed that CBCT had a higher diagnostic value than PA radiography. NPV was 100% for CBCT. It means that in all cases detected to be normally filled by CBCT, the teeth were found to be actually filled normally by the gold standard. The PPV was 86%, which shows that there were some teeth that were detected to be over-extended or under-extended by CBCT while they were found to be normally filled by the gold standard.FundaYılmaz et al (2017) were conducted an study to evaluate the accuracy of working length determination by using an electronic apex locator, digital periapical radiography, and CBCT imaging with different voxels and FOVs. They reported that all CBCT images obtained at different FOVs with voxel sizes less than 0.3 mm^3performed similarly and better than intraoral periapical radiography in the determination of endodontic working length measurement(18).

Michetti et al. showed a very strong association between CBCT data and histological measurements(20). Patel et al, and Sogur et al. evaluated the diagnostic accuracy of CBCT and intraoral radiography for detection of small periapical lesions in vitro and showed that sensitivity, specificity and Az value in ROC analyses in CBCT were greater than those in intraoral radiography(21, 22).

Torabinejad et al. assessed the diagnostic value of CBCT compared to periapical radiography for detection of small periapical lesions in human skulls in vitro and showed that the diagnostic value of CBCT was poor for defects smaller than 0.8 mm, moderate to good for defects with a diameter between 0.8-1.4 mm and excellent for defects with a diameter larger than 1.4 mm. They concluded that periapical radiography has a poor diagnostic value for detection of defects of any size(23). Li Cheng et al. (11)in 2011 evaluated the agreement between the results of CBCT and PA radiography for detection of root filling length and reported that in 30.3% of cases found to have adequate root filling length by PA radiography, inappropriate length was revealed by CBCT. They also stated that among cases with0-0.5 mm distance between root filling and radiographic apex on PA radiographs, root filling length was detected to be in the normal range in 47.6% by CBCT; in 40%, this distance was detected to be 0.5-1 mm, in 76%,this distance was found to be 1-1.5 mm and in 69.7%,this distance was found to be 1.5-2 mm. The results were more reliable in teethwith 0.5-1 mm distance between root filling and radiographic apex on PA radiographs. Our results showed that 100% of teeth with 0.5-1 mm distance between root filling and radiographic apex on PA radiographs were detected to have normal root filling length by the gold standard and CBCT. To put it simply, we categorized the distance between root filling and radiographic apex as follows:

Distance 1: 0-0.5 mm
Distance 2: 0.5-1 mm
Distance 3: 1-1.5 mm
Distance 4: 1.5-2 mm

The percentage of normal cases detected by CBCT compared to PA radiography for each distance in the study by Li-Cheng et al (11) was as follows: 4<1<3<2 with percentages as follows: 45<47<76<89.

The percentage of normal cases detected by CBCT compared to PA radiography for each distance in our study was as follows: 4<1<3<2 with the percentages as follows: 57<85<97<100%.

The percentage of cases detected to be normal by all three methods was as follows: 4<1<3<2 with the percentages as follows: 42<66<78<87.

Both our study and that of Li-Cheng(11)showed that when the distance between the root filling and radiographic apex is 0.5-1 mm on PA radiographs, there is a high likelihood that CBCT detects the root filling length to be normal. Our study showed that when this distance was 0.5-1 mm on PA radiographs, there was a high likelihood that the root filling length is actually normal (0-2 mm distance). The lowest accuracy of PA radiography is when the distance is 1.5 to 2 mm since the gold standard assessment showed that in only half of these cases this length was actually normal. In all distances, the agreement of PA radiography and CBCT in our study was higher than that of Li-Cheng. The diagnostic value of CBCT for detection of root filling length in our study was higher than that of PA radiography. But it does not mean that CBCT can routinely replace PA radiography for endodontic diagnosis. In our study, although the diagnostic value of PA radiography was found to be less than that of CBCT for detection of root filling length, the results of PA radiography were considerably in agreement with the gold standard and CBCT (7% disagreement in our study versus 30.3% disagreement in the study by Li-Cheng(11)). ANOVA found no significant difference among the three methods in our study. Torabinejad et al. reported that PA radiography was inefficient for detection of small PA lesions. In contrast, our study revealed that PA radiography was acceptable for assessment of root filling length and since the patient radiation dose is lower in this method and it is less costly (24), PA radiography can obviate the paraclincial diagnostic needs in many cases and provide the clinician with adequate diagnostic information. CBCT can be requested for special cases requiring adjunct radiography i.e., in cases where clinical findings are not in agreement with PA radiographic findings. Cost effectiveness should always be considered and the diagnostic information obtained by CBCT must be weighed against the higher radiation dose received and the higher cost(5). CBCT should be the imaging modality of choice when evaluating the non-healing of previous endodontic treatment to help determine the need for further treatment, such as non-surgical, surgical or extraction or non-surgical re-treatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations(16). Franziska(5) reported that the results of CBCT had high agreement with EAL(Electric Apex locator) and concluded that CBCT should not be recommended for determination of working length as a replacement for EAL. However, they recommended that if the patient has a recent CBCT scan, it can be used for working length determination and there would be no need to take a primary radiograph for endodontic treatment. Canal length can be determined on CBCT scans with acceptable accuracy. CBCT scans can also provide valuable information about the root canal morphology. Moreover, the importance of CBCT is highlighted when EAL cannot provide accurate results (5).

The diagnostic value reported for CBCT in our study was probably true. However, the results obtained for PA radiography in our study had high agreement with those of CBCT and the gold standard, which was in contrast to the findings of Torabinejad(23) and Li-Cheng(11). PA radiography may actually have high accuracy for determination of root filling length in contrast to its low accuracy for detection of small PA lesions showed by Torabinejad(23) or determination of presence of cortical perforation and apical periodontitis showed by Seonabkim(25). However, there is another possibility that the obtained results for PA radiography in our study may be due to its in vitro design. CBCT images are not likely to be influenced by the in vitro or in vivo design of studies due to their 3D nature but PA radiography has a 2D nature and may overestimate the results in vitro due to the absence of superimposition of anatomical landmarks. However, in this study, we tried to simulate the clinical setting by mounting the teeth in gypsum blocks to simulate the distance between film and teeth and minimize errors in the results.

CONCLUSION

CBCT had higher sensitivity and specificity and diagnostic value than PA radiography in our study. NPV and ppv were 100% and 86% for CBCT, where 98.1 and 88 was calculated for PA radiography. But intraoralperiapicalradiography is a valuable imaging modality in endodontic treatment since it provides good diagnostic information with high resolution, low patient radiation dose and low cost. CBCT can be requested for specific cases as an adjunct to provide further diagnostic information.

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