Diagnostic efficacy of different cone beam computed tomography scanning protocols in the detection of chemically simulated external root resorption

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Objectives. The aim of this study was to evaluate the efficacy of different high-resolution cone beam computed tomography protocols in the diagnosis of chemically simulated external root resorption (ERR).

Study Design. ERR was simulated in 3 sizes by using an acid decalcification protocol in the cervical, middle, and apical thirds of 30 single-rooted premolars. Four scans of each tooth were acquired with different voxel sizes: 0.080, 0.085, 0.120, and 0.133 mm. The images were analyzed by 2 blinded evaluators for the presence of ERR. The evaluation of diagnostic performance was based on receiver operating characteristic (ROC) curve analysis.

Results. No statistically significant differences were found in the detection of ERR with regard to lesion sizes or the different root thirds. Areas under the ROC curve were 0.901, 0.892, 0.887, and 0.767 for voxel sizes of 0.080, 0.085, 0.120, and 0.133 mm, respectively. Voxel sizes of 0.080 and 0.085 mm presented significantly larger areas under the ROC curve compared with the voxel size of 0.133 mm. There were no statistically significant differences among the protocols with the use of voxel sizes of 0.080, 0.085, and 0.120 mm.

Conclusions. Cone beam computed tomography examinations with higher-resolution protocols demonstrated better performance in the diagnosis of ERR. Further investigations using simulations that more closely resemble the actual ERR process are warranted. (Oral Surg Oral Med Oral Pathol Oral Radiol 2020;130:322−327)

External root resorption (ERR) leads to irreversible loss of mineralized tissue and is associated with both physiologic and pathologic processes.[1] Radiography is the first step in the diagnosis of this lesion, and identification of the exact location of the lesion and the stage of resorption directly affects treatment planning.[2]

Several authors have investigated the capacity of imaging examinations to aid in the diagnosis of ERR by using methodologies involving simulations of resorption, as proposed by Andreasen et al.,[3] for both external resorption and internal resorption. Other authors made minor modifications to the diameters and depths of the cavities by using the same drill simulation principle for the evaluation of the diagnostic capacity of both intraoral radiographic and cone beam computed tomography (CBCT) examinations.[4-11]

A new methodology that has recently been developed for simulated dental resorption uses acid decalcification, with the aim to more closely simulate the resorption process (i.e., with a less regular surface).[12] Sousa Melo et al.,[13] in their evaluation of the diagnosis of chemically induced radicular resorptions, sought to simulate intercurrences of orthodontic treatment in the apical third. Another study by Sönmez et al.[14] used a hybrid simulated resorption process to chemomechanically create ERR cavities. Those authors concluded that CBCT images acquired at 4 voxel sizes performed similarly in the quantification of artificial ERR, with a clinically insignificant distinction among the CBCT software programs used.[14]

Using CBCT voxel sizes of 0.250 mm, 0.200 mm, and 0.166 mm, Deliga Schröder et al. demonstrated that natural ERRs are not easily observed, regardless of voxel size, and yield lower accuracy values than those reported in previous studies investigating artificial cavities.[15] Nonetheless, some protocols involved the use of smaller voxel sizes, longer exposure times, and higher current (i.e., increased milliamperes), and this invariably resulted in better image resolution but also led to increased radiation dose to the patient.[16]

According to American Association of Endodontics (AAE) and SEDENTEX guidelines, CBCT should be utilized on a case-by-case basis, taking into consideration the risks and benefits of exposure of the patient to ionizing radiation. In these situations, a small, high-resolution field of view (FOV) examination should be

Statement of Clinical Relevance

The guidelines that support the capacity of cone beam computed tomography to aid in diagnosing external root resorption are supported by studies that use the drill protocol. This study used acid demineralization and compared the potential differences in diagnosis according to the methodology used.

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chosen for ERR diagnosis.[17] CBCT has been studied with respect to improved diagnosis of root and periapical lesions.[18-20] The use of CBCT has been demonstrated to significantly improve diagnostic efficacy in the detection of internal root resorption and ERR.[21-25] However, the lesions in these studies were created with the drill protocol, and the voxel sizes were no smaller than 0.200 mm.

Currently, high-definition protocols are available in many CBCT units, yet few studies have analyzed the effect of smaller voxel sizes on diagnosis. Sönmez et al.[14] compared the accuracy of linear and volumetric measurements of ERR cavities with images acquired by using voxel sizes of 0.075, 0.100, 0.150, and 0.200 mm; however, the authors did not evaluate diagnostic accuracy. In view of the above, the objective of the present study was to compare the diagnostic efficacy of CBCT, using different scanners and protocols, in the detection of chemically simulated ERR. The null hypothesis stated that there would be no statistically significant differences in efficacy among the various experimental protocols.

MATERIALS AND METHODS

The present investigation was approved by the Research Committee of the Faculty of Dentistry of the University (No. 936182). The study used 30 human single-rooted premolars, with the buccal root surfaces subdivided into thirds—cervical, middle, and apical—totaling 90 sites. In each third, there were 4 possibilities for ERR simulation, which were randomly chosen: small (0.6 mm); medium (1.2 mm); large (1.8 mm); and absent. In total, there were 22 small, 23 medium, and 22 large lesions, and 23 thirds with no simulation.

ERR simulation was performed by using an acid demineralization process. For this, the teeth were partially embedded in plaster, leaving only the buccal root faces free (Figure 1A). The teeth were then arranged in a vacuum plasticizer so that the buccal surfaces were covered by a plastic plaque. After plaque removal, perforations were made in the plaque by using cylindrical drills with diameters of 0.6, 1.2, and 1.8 mm. The location of these perforations corresponded to the respective root thirds according to the randomization protocol (Figure 1B). Subsequently, a thin layer of composite resin was added to the plaque, avoiding the perforations. The plaque was then placed back onto the root surface and cured. Thus, the root surface was exposed to the action of acid only at the perforated sites (Figure 1C). Lesions of different sizes in each root third are depicted in Figure 1D.

The acid demineralization process adhered to the protocol developed by Silveira et al; according to this protocol, each demineralization cycle consisted of treatment with 5% nitric acid solution for 12 hours, 8% sodium hypochlorite for 10 minutes, and 5% nitric acid solution for resorption lesions.[12] After the procedure, the teeth were removed from the plaque and plaster, washed, and stored in deionized water to arrest the process.

CBCT images were acquired individually. Each tooth was placed in an alveolus of a dry human mandible covered by a wax layer for soft tissue simulation and then immersed in a box filled with water. Two CBCT devices were used: OP300 (Instrumentarium Dental, Helsinki, Finland) and PaX-i3D (Vatech Co, Hwaseong, Gyeonggi, South Korea). With each device, 2 small FOV acquisitions of each tooth were performed with alternating voxel sizes (Table I). All acquisitions were performed with fixed kilovoltage peak (kVp) and current in milliamperes (mA).

The acquired images were exported in DICOM (Digital Imaging and Communications in Medicine) format

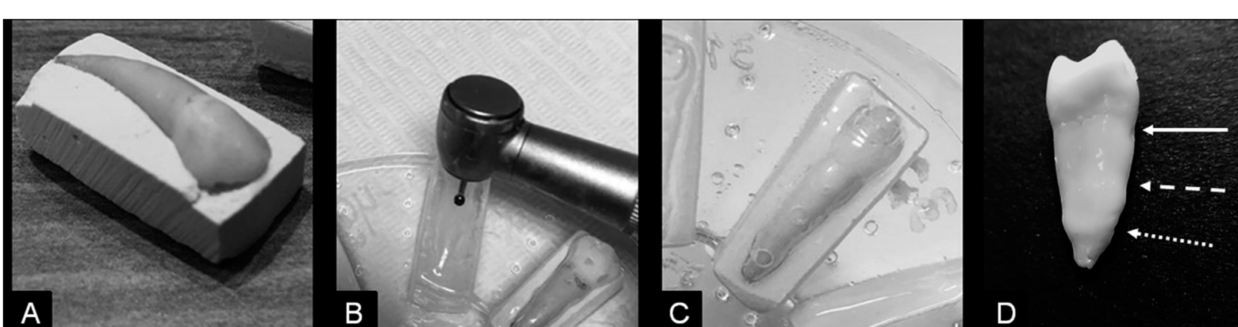

Fig. 1. **A,** Tooth partly embedded in plaster. **B,** Mechanical preparation of perforations in the plastic plaque to allow penetration of acid during chemically induced lesion creation. **C,** Plastic plaque with perforations sealed over the tooth to allow chemical demineralization only at the parts of the root exposed by the perforations. **D,** Tooth with 3 lesion sizes: large in the cervical third *(solid arrow)*, medium in the middle third *(dashed arrow)*, and small in the apical third *(dotted arrow)*.

Table I. Characteristics of image acquisition protocols

Protocol	*CBCT unit*	*FOV (cm)*	*Voxel size (mm)*	*Tube voltage/Current*	*Number of basis images*
1	PaX-i3D	5 × 5	0.080	85 kVp/5.2 mA	624
2	OP300	6 × 4	0.085	90 kVp/10 mA	705
3	PaX-i3D	5 × 5	0.120	85 kVp/5.2 mA	416
4	OP300	6 × 4	0.133	90 kVp/10 mA	451

CBCT, cone beam computed tomography; *FOV,* field of view.

and imported into OnDemand software (Cybermed Inc., Seoul, South Korea). Two blinded and calibrated oral and maxillofacial radiologists evaluated the presence or absence of resorption in each third of the root surfaces. A representative image of the same tooth acquired with each voxel size is shown in Figure 2.

The calibration session included presenting examples of root resorption similar to what was expected in the study sample and orientation on software use. All evaluations were repeated while the evaluators were blinded to the previous scores 2 weeks after the initial viewings to assess intraexaminer agreement by using the kappa coefficient. Interexaminer agreement was also verified by using the kappa coefficient. In cases of disagreement, the observers reached consensus through discussion, and the consensus data were used to calculate sensitivity, specificity, and accuracy. The 4 voxel sizes were independently analyzed, and the association of voxel size with lesion size and lesion location was analyzed by using the χ^2 test. The diagnostic efficacy of the various voxel protocols was assessed from the sensitivity, specificity, and accuracy results. Furthermore, comparison among protocols was performed by using receiver operating characteristic (ROC) curve analysis. Statistical analysis was performed by using MedCalc version 17.9.7 (MedCalc, Ostend, Belgium). The level of statistical significance was set at 5%.

RESULTS

The intraexaminer agreement results from the 2 examiners were 0.83 and 0.86, and this was interpreted as almost perfect agreement.[26] The interexaminer agreement as measured with the kappa coefficient was 0.77 (standard error 0.03), which was interpreted as substantial agreement.[26] Nevertheless, statistical analysis was performed on the data derived from consensus.

The highest percentage of ERR identification (100%) was for large lesions in protocol 1 (0.080 mm voxel size). The lowest percentage (77%) was for small lesions in protocol 4 (0.133 mm voxel size). With regard to the size of the ERR, protocols 2 and 3 were better in detecting small lesions, whereas protocol 1

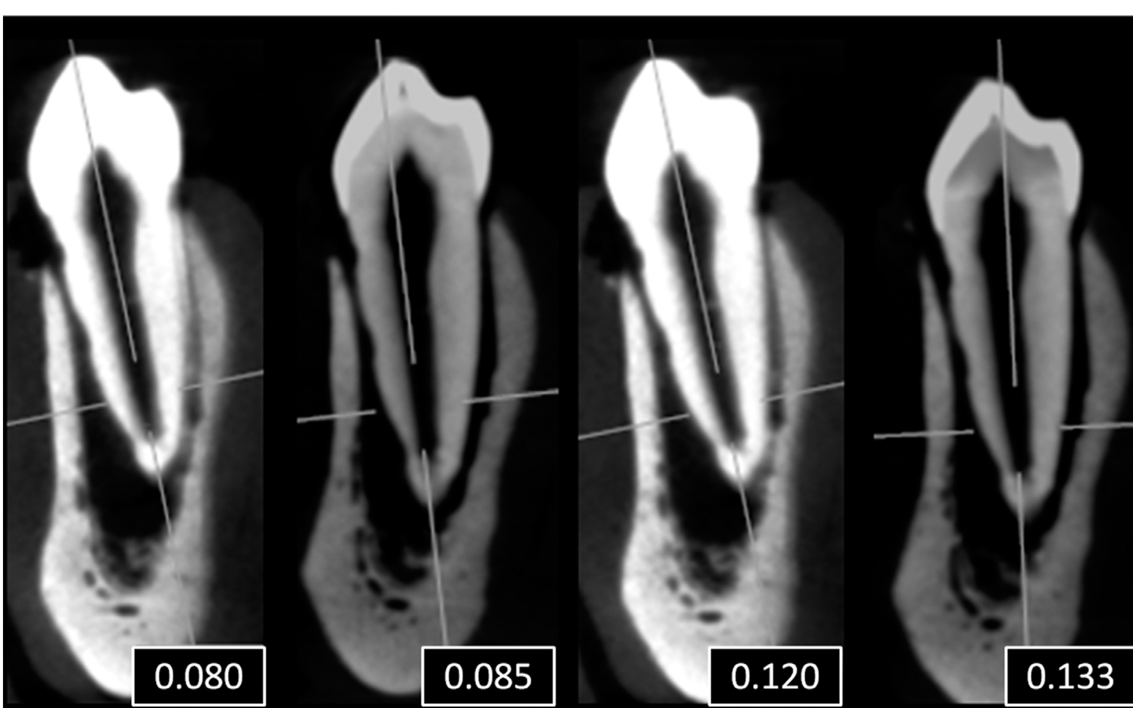

Fig. 2. Cone beam computed tomography (CBCT) images of the same tooth acquired with each of the voxel sizes.

Table II. Percentage of identified root resorptions considering lesion size and lesion location, and the χ^2 values

		Protocol (voxel)				
		1 (0.080 mm)	*2 (0.085 mm)*	*3 (0.120 mm)*	*4 (0.133 mm)*	*Pearson χ^2*
	Small	82%	86%	86%	77%	
Lesion size	Medium	91%	87%	87%	87%	P = .926
	Large	100%	95%	91%	91%	
Lesion location	Cervical	93%	93%	97%	90%	P = .989
	Middle	93%	87%	90%	87%	
	Apical	93%	90%	87%	90%	

was better in detecting medium and large resorptions. With regard to location, protocol 3 was associated with better detection of lesions in the cervical region, whereas protocol 1 demonstrated higher percentages in the middle and apical regions (Table II). However, according to the χ^2 test, there was no statistically significant association between the detection of lesions based on size of resorption (P = .926) or location (P = .989) (see Table II).

The results of sensitivity, specificity, accuracy, and area under the ROC curve (AUC) analysis for the diagnosis of all simulated ERR for each protocol are summarized in Table III. Protocol 1 yielded the highest accuracy (0.91) and AUC (0.901), whereas protocol 4 produced the lowest accuracy (0.83) and AUC (0.767). Comparison of ROC curves for the 4 voxel sizes tested is shown in Figure 3. No significant differences were found among protocols 1, 2, and 3. Protocol 4 demonstrated the lowest AUC and was significantly different from protocols 1 and 2 ($P < .05$).

DISCUSSION

Several studies have used the drill wear protocol to evaluate the efficacy of CBCT in the diagnosis of simulated root resorptions.[3-11,21-23] However, the acid simulation protocol provides a resorption model with features that more closely resemble the natural process.[12] The present study used the acid demineralization methodology developed by Silveira et al.,[12] which was adapted for ERR simulation. Diameters of resorptions similar to those proposed in the drill simulation method were used. In this manner, it was possible to compare the differences in diagnostic results according to the methodology used.

Although Sousa Melo et al.[13] simulated external resorptions chemically, their study simulated larger lesions (3 mm) and in the apical root third only. The present study simulated different locations and diameters, aiming to establish comparisons of our results with those reported in the literature.

Many CBCT studies investigating ERR diagnosis by using mechanical simulation of the lesions have reported sensitivity and specificity values between 90% and 100%.[7-10,22] These high values may indicate an easier challenge for the evaluator to detect these cavities with well-defined limits and depths. The present study, even when using the higher-resolution image acquisition protocols that result from smaller voxels, revealed lower sensitivity and specificity. This result may be explained by the irregular characteristics of the acid demineralization−simulated lesions, approaching diagnostic reality in real-world conditions. Moreover, various studies have investigated the diagnosis of root resorption by using large FOV CBCT devices.[4-7,9-13,22] However, the AAE recommends a small FOV for identification and differentiation of external as well as internal root resorption.[14] In keeping with these guidelines, the present study used only small FOVs with high-resolution protocols.

The most commonly tested voxel sizes for ERR evaluation are 0.400, 0.300, and 0.200 mm.[4,6,7,9-13,22] Liedke et al.[22] investigated 3 protocols for root resorption simulated by using drills and observed that scans with the voxel sizes of 0.200 and 0.300 mm resulted in better performance compared with those with a 0.400 mm voxel size. In view of this, the authors suggested the use of a 0.300 mm voxel size because it presented a result similar to that of a smaller voxel size with lower radiation dose. When testing voxel sizes of 0.300, 0.250, and 0.200 mm, Neves et al.[9] observed that the smaller the voxel (and the higher the resolution), the greater the diagnostic efficacy for ERR; therefore, the smallest voxel available should be used.

Table III. Sensitivity, specificity, accuracy, and area under the curve (AUC) for each protocol in the diagnosis of simulated external root resorption (ERR)

Protocol (voxel size)	*Sensitivity*	*Specificity*	*Accuracy*	*AUC*
1 (0.080 mm)	0.91	0.91	0.91	0.901^{A}
2 (0.085 mm)	0.87	0.96	0.89	0.892^{A}
3 (0.120 mm)	0.88	0.87	0.88	0.887^{AB}
4 (0.133 mm)	0.85	0.78	0.83	0.767^{B}

Different letters indicate significant differences among protocols.

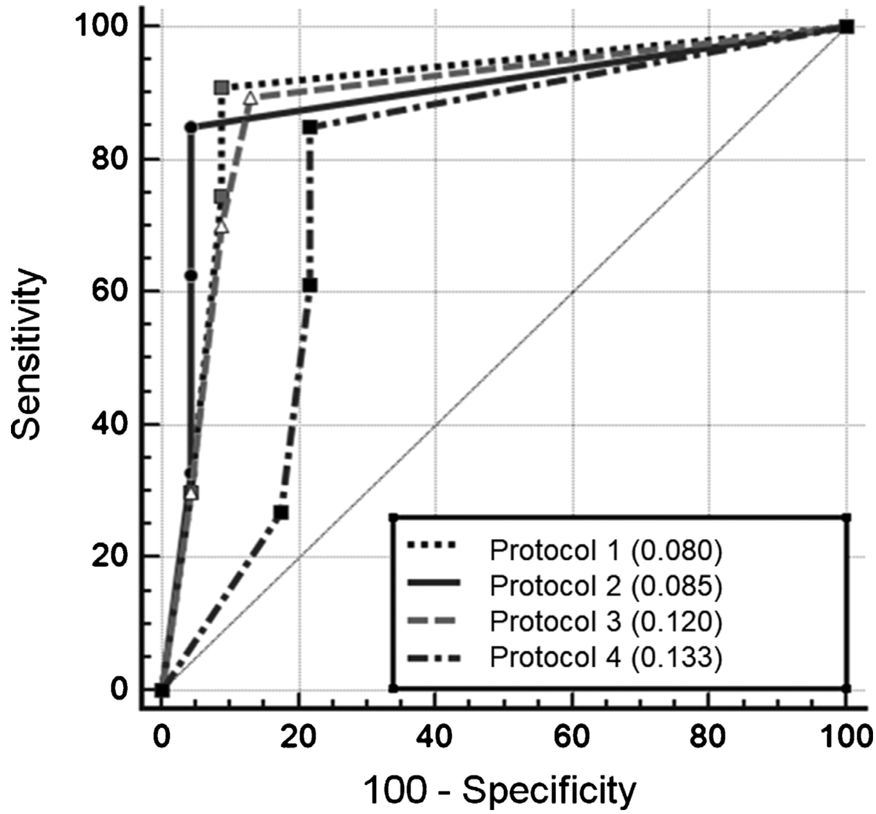

Fig. 3. Receiving operator characteristic (ROC) curves for each of the 4 protocols.

In the present study, only small voxels (0.080, 0.085, 0.120, and 0.133 mm), which yield higher resolution, were evaluated. With use of the PaX-i3D system, we did not observe any statistically significant differences in diagnostic outcomes between the protocols with voxel sizes of 0.080 and 0.120 mm. With the OP300 system, the smaller voxel (0.085 mm) demonstrated better results compared with a voxel size of 0.133 mm, which produced the second-best resolution available when using this system.

Liedke et al.[22] reported good sensitivity and specificity values regardless of the size and location of the lesion. Similarly, we confirmed that size and location did not influence the diagnostic values for ERR. However, the findings on multislice computed tomography (CT) scans demonstrate greater difficulty in detecting small root resorptions in the apical root third.[21]

Small FOV CBCT units and high-resolution acquisition protocols, with variations in voxel sizes and numbers of basis images, were selected for this study. Both units had the same focal spot size (0.5 cm), and although the protocols were similar, each unit had its own construction and operation specifications. But these were not used in the research and that may have influenced the results. In addition, the *in vitro* studies that support the AAE and SEDENTEX guidelines with regard to imaging examination recommendations for ERR diagnosis used drill simulations and only 1 CBCT device.[8,22]

CONCLUSIONS

From the results of this study, it can be concluded that examinations made by using small FOV CBCT units with higher-resolution protocols demonstrated better performance in the diagnosis of ERR compared with scans made with larger voxels. Further investigations with methodologies using simulations more closely resembling the natural ERR process and a larger number of CBCT units are needed.

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