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DIAGNOSTIC VALUE OF TWO MODELS OF CONE-BEAM COMPUTED TOMOGRAPHY IN EVALUATION OF SIMULATED EXTERNAL ROOT RESORPTION: ANINVITRO STUDY

MAHNAZ SHEIKHI[a], ABBAS ALI KHADEMI[b], AITINTORABINIA[c1] AND ALIREZA SAEIDI[d]

[a]Torabinejad Dental Research Center, Department of Radiology, School of Dentistry, Isfahan, University of Medical Sciences, Isfahan, Iran
[b]Torabinejad Dental Research Center, Department of Endodontics, School of Dentistry, Isfahan, University of Medical Sciences, Isfahan, Iran
[c]Dental Students' Research Center, Department of Radiology, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[d]Students' Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Voxel resolution and field of view of cone-beam computed tomography affect its diagnostic capability. The aim of this study was to compare two modes of CBCT (Sirona Dental Systems Inc, Bensheim, Germany) and (Sirona Dental Systems GmbH, Bensheim, Germany). Thirty small(0.5 mm in depth and 0.5 mmin diameter) and thirty large(1 mm in depth and 1 mmin diameter) cavities were simulated on the buccal surface of teeth at three levels in a random manner: 10 teeth with small cavities in the cervical and large cavities in the apical, 10 teeth with small cavities in the middle and large cavities in the cervical, 10 teeth with small cavities in the apical and large cavities in the middle thirds. The root was inserted in the socket, and CBCT scans were taken in both modes. The images were analyzed by two observers to diagnose the presence and the size of the cavity. The sensitivity and specificity of simulated cavities were analyzed. There was a significant difference between the two imaging modes in diagnosing the small cavities (P=0.02).The sensitivity of the "Inc mode" in detecting the small cavities was lower than that of the "GmbH mode". This study suggested that a smaller FOV and larger voxel size, for example 0.3, in Gmbh mode in comparison to 0.15 in the Inc mode of CBCT is preferred for the diagnosisof ERR.

KEYWORDS: Cone-beam Computed Tomography; Root Resorption; Diagnosis

External root resorption (ERR) is an irreversible process that may lead to the loss of the tooth andis a process of resorption of tissues like dentin, cementumand the alveolar bone (Bakland, 1992).ERR is diagnosed based on radiographic and clinical examinations(Bakland, 1992). Root resorption usually does not have any clinical symptoms or signs (Sheikhi and Maleki, 2011). The main diagnostic tool for detection of root resorptionis radiographic examination, especially when there are no clinical symptoms andsigns (Nance et al., 2000).

Conventional radiographic techniques are used to follow ERR (1) but digital techniques are more reliable than conventional radiographic techniques for detection of ERR However, the accuracy of digital radiography is controversial (Durack et al., 2011).

Small lesions on the buccal and lingual surfaces of teeth pose the main difficulty in the diagnosis of ERR (Dalili et al., 2012).

CBCT has better diagnostic accuracy compared to conventional and digital radiography (Estrela et al., 2009). Exact diagnosis of the location and size of ERR would be most significant in predicting the prognosis of the treatment (Sheikhi et al., 2012).

Gabriela et al showed that using 0.3 mm voxel resolution would be the best approach in diagnosing RR using CBCT with lower x ray exposure Few studies are available on the detection of ERR by CBCT(PATEL ET AL., 2009).

Or on the effect of voxel size and field of view on such diagnosis (Dalili et al., 2012, Liedke et al., 2009). Therefore the aim of this study was to compare the diagnostic capacity of CBCT with different voxel resolution andFOV in detecting simulated ERRs with different sizes and locations on the buccal surface.

MATERIALS AND METHODS

Thirty human mandibular incisors were randomly numbered from 1 to 30 and their root portions were divided into cervical, middle and apical thirds. A total of 90 thirds were obtained. For each root third (cervical, middle and apical), there were 3 simulation possibilities: small, large or no cavity. Therefore, there were 9 possible combinations, and for each combination (third*size),10 teeth were randomly selected. The teeth

[1]Corresponding author

were divided into 3 groups. The number,location and size of all the cavities were listed and saved for each tooth.

10 teeth:small cavities in the cervical and large cavities in the apical thirds.

10 teeth:small cavities in the apical and large cavities in the middle thirds.

10 teeth:small cavities in the apical and large cavities in the middle thirds.

To simulate external root resorption,the teeth were placed in a holder and cavities measuring 0.5 and 1mm in diameter and 0.5 and 1mm in depth(small and large) were drilled with a round diamond bur (Figure 1).

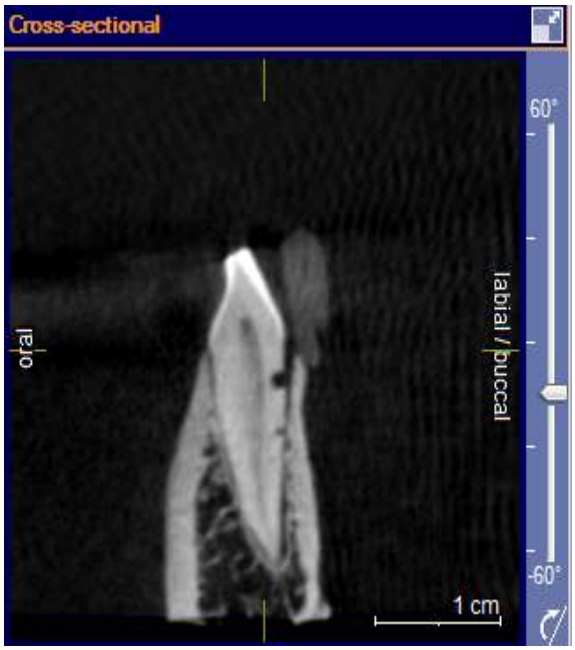

Figure 1: Cross-sectional images revealed small external root resorption cavities on the mandibular incisors in the the Gmbh mode

The teeth were removed carefully from the holder and separately repositioned in the alveolar socket of a cadaver skull.

Soft tissue simulation was conducted by covering the bone with wax plates, which reduced artifacts in the image (Figure 2). This complex was then set on the desk of GALILEOUS CBCT machine. Depending on the voxel resolution and FOV size, volumetric images were acquired using two modes of GALILEOS Comfort 3D imaging system(Sirona Dental Systems Inc., Bensheim, Germany): (FOV:15*15*15; voxel size: 0.15) and GALILEOS Comfort 3D imaging system(Sirona Dental Systems GmbH, Bensheim, Germany) (FOV:15*15*12; voxel size: 0.3).

Exposure parameters for (Sirona Dental Systems Inc) mode were 85 kVp, 7mA and14 seconds. The above-mentioned steps were repeated by the (Sirona Dental Systems GmbH) with an exposure parameter of 90kVp,12 mA and 14seconds. For both of them 270 rotations for each scan produced 200 projections.

The images were saved in SVG file format and reconstructed using GALAXIS Viewer software.

Axial, sagittal and cross-sectional views were obtained. Axial images with a thickness and interval of 1mm were prepared. Cross-sectional images with a thickness of 1mm and an interval of 1mm were also prepared for each root. The images were analyzed by two blinded radiologists. The same observation was repeated for each mode at a 15-day interval. The results at the two time periods were evaluated using kappa,which proved above0.8 at 95% CI.

The voxel resolution and FOV were analyzed independently for association with three planes (axial, cross-sectional and sagittal), resorption size (small, large) and its root location(cervical,middle and apical third)by the McNemar test. The significance was defined at $P<0.05$. SPSS 11.0 (SPSS Inc., Chicago, IL, USA) was used for the analysis. Statistical significance was set at a confidence level of 95%.

All the root surfaces were carefully evaluated and any root resorption was recorded in a checklist.

RESULTS

In this experimental study, 100% of the cavities were correctly identified in the cross-sectional examination (Sirona Dental Systems GmbH) and 98.33% of the cavities were correctly identified in the cross-sectional examination (Sirona Dental Systems Inc).

All the resorptions (100%) were correctly identified in the sagittal section (Sirona Dental Systems GmbH) and 96.66% of the cavities were correctly identified in the sagittal section(Sirona Dental Systems Inc).

A total of 80% of the cavities were correctly identified in the trans-axialsection(Sirona Dental Systems GmbH) and 43.33% of the cavities were correctly

identified in the trans-axial section(Sirona Dental Systems Inc).

In addition, the percentage of correct diagnoses of large cavities was 100% in the cross-sectional view (Sirona Dental Systems Gmband Sirona Dental Systems Inc).

The percentages of correct diagnoses of large cavities were 100% in the sagittal view of (Sirona Dental Systems GmbH and Sirona Dental Systems Inc), 96% in trans-axial view of (Sirona Dental Systems GmbH) and 76.66% in trans-axial view of (Sirona Dental Systems Inc).

Tables 1 and 2show the frequencies of making a correct identification of ERR cavities in both the (Sirona Dental Systems GmbH) and (Sirona Dental Systems Inc).

There was a difference between these two imaging modes for the small cavities (P=0.02) but there was no difference for large cavities(P=0.1).

The sensitivity and specificity of all the CBCT imaging modes are summarized in Tables 1 and 2.

Table 1: Correct diagnosis of simulated ERR cavities using CBCT

Location	Simulated RR Cavities	Number	GmbH Cross	GmbH Sagittal	GmbHTrans-axial	Inccross	IncSagital	IncTrans-axial
Total Apical	Small+large	20	20 Se:100%	19 Se:95%	13 Se:65%	20 Se:100%	19 Se:95%	5 Se:25%
Total Middle	Small+large	20	20 Se:100%	20 Se:100%	19 Se:95%	20 Se:100%	19 Se:95%	11 Se:55%
Total Cervical	Small+large	20	20 Se:100%	20 Se:100%	16 Se:80%	19 Se:95%	20 Se:100%	11 Se:55%

Table 2: Correct diagnosis of simulated ERR cavities using CBCT (in the apical, middle and cervical thirds)

Location	Simulated RR Cavities	Number	GmbHCross (%) N	GmbH Sagittal (%)N	GmbH Transaxial (%) N	IncCross N(%)	IncSagital N(%)	Inc Trans-axial N(%)
Apical	small	10	10 Se:100%	9 Se:90%	4 Se:40%	10 Se:100%	9 Se:90%	1 Se:10%
Apical	large	10	10 Se:100%	10 Se:100%	9 Se:90%	10 Se:100%	10 Se:100%	4 Se:40%
Middle	small	10	10 Se:100%	10 Se:100%	9 Se:90%	10 Se:100%	9 Se:90%	1 Se:10%
Middle	large	10	10 Se:100%	10 Se:100%	10 Se:100%	10 Se:100%	10 Se:100%	9 Se:90%
Cervical	small	10	10 Se:100%	10 Se:100%	6 Se:60%	10 Se:100%	10 Se:100%	1 Se:10%
Cervical	large	10	10 Se:100%	10 Se:100%	10 Se:100%	9 Se:90%	10 Se:100%	10 Se:100%
Total	small	10	30 Se:100%	10 Se:100%	19 Se:63.33%	29 Se:96%	28 Se:93.33%	3 Se:10%
Total	large	10	30 Se:100%	30 Se:100%	29 Se:96%	30 Se:100%	30 Se:100%	23 Se:76.66%
T	Small+large	60	60 Se:100%	60 Se:100%	48 Se:80%	59 Se:98.33%	58 Se:96.66	26 Se:43.33%

*se=sensitivity

*Specificity in all of the case in both cbct were 100%

DISCUSSION

The aim of this study was to compare the diagnostic capacity of CBCT with different voxel resolutions andFOVs in detecting simulated ERRs with different sizes and locations on the buccal surface.

Previous studies have shown that the 2D radiography is not accurate in detecting root resorption, particulary in the apical third of the root(Bakland, 1992, Dalili et al., 2012). Rootresorption is a 3D eventand the extent of RRmust be measured(Bakland, 1992).In CBCT the evaluation of root surface from different perspectives, i.e.trans-axial, cross-sectional and sagittal views, provides specific advantages of being able to determine the stage of RR more accurately.

The prognosis and treatment of RR depend on the location, size, and root surface involved. Early diagnosis would be a great advantage to start treatment and improve the success rate of treatment. Cone-beam computed tomography appears tobe a diagnostic tool for confirming the presence of RR; CBCT enables further assessment of the area of interest, contributing to the correct treatment modality for the real pathology.The use of CBCT can be invaluable in the treatment process. However, a small voxel size will help represent fine details. The voxel size has a direct effect on image resolution and noise(da Silveira et al., 2014). Studies have shown that decreasing the voxelsize increases thenoise. In addition, a voxel size less than 0.04mm didnot enhance resolution but resulted in more noise. With small FOVs,a 0.2mm voxel size resulted in better contrast and resolution compared to voxel sizes of smaller dimensions(Shokri et al., 2013). The size of the FOV depends primarily on the detector size and shape, the beam projection geometry and the ability to collimate the beam. As a result,field size limitation ensures that an optimal FOV can be selected for each patient, based on disease presentation and the region to be imaged.

This study evaluated two modes of CBCTwith voxel sizes (0.3, 0.15) and FOV (15*15*15 and 15*15*12) in the detection of simulated ERR.In this investigation, small cavities measuring 0.5mm in depth and 0.5mm in diameter, and large cavities measuring 1mm in depth and 1mm in diameterwere drilled at three levels(cervical,middle and apical).

The results of this study showed no significant differences between the two observers; therefore, the results of the two observers were assessed simultaneously. In CBCT, Gmbh protocol in comparison withInc protocols has a higher accuracy and higher diagnostic capacity in correct diagnosis of root resorption areas in the middle and cervical rather than the apical, and cross-sectional section has a higher diagnostic capacity than other planes. Also large cavities and relatively small cavities are better identified. The cavities in the apical third were best observed with a voxel size of 0.3 and the smaller FOV.

The location of the ERR affects the diagnostic capacity of the CBCT. The results of this study showed that the accuracy of the two protocols in detection of the cervical third and middle third of the root region was higher than the apical third, which might be attributed to smaller apical areas of the root section. The least sensitivity with small cavities was observed in the apical third, consistent with the results reported by Dalili, daSilveira and Shokri(Sheikhi et al., 2012, da Silveira et al., 2014, Shokri et al., 2013).

In this study the greatest sensitivity in relation to the cavity was observed in the middle third, consistent with the results of a study by Neves(Neves et al., 2012).

Silveria et al showed that the location of the RR affects the diagnostic accuracy of the CBCT and the RR in the middle and cervical thirds of the root is diagnosed more accurately than the apical third(da Silveira et al., 2014). This result is consistent with our study. The frequencies of correct diagnoses in the apical,middle and cervical thirds in each mode and in each cavity size were higher than those of studies by Dalili et al and Da Silveira et al(Dalili et al., 2012, da Silveira et al., 2014)because the cavities in the present study were larger than those in those studies.

The size of the ERR affects the diagnostic capacity of the CBCT. The accuracy of both protocols in detectinglarge cavities is more than a small one.The lowersensitivity in small cavities obtained in both modes of CBCT in comparison with large cavities is consistent with previous studies(5,,10–12).

The results of a study by Neves et al showed that increasing the size of RR increases the sensitivity and specificity of the diagnosis(Neves et al., 2012), consistent with the results of the present study. In a study carried out by Dalili two cavities were used; the small one was 0.25 mm in depth and 0.5 mm in diameter and the large one

was 0.5 mm in depth and 1 mm in diameter; the least sensitivity was observedin relation to the small apical cavity(Dalili et al., 2012), consistent with our study.

In CBCT the evaluation of root surface is carried out from different perspectives, i.e.trans-axial, cross-sectional and sagittal views, which might increase the diagnostic capacity of CBCT. The results showed that the image plane affects the diagnostic ability of CBCT. The best accuracy was obtained in the cross-sectional view.

The voxel size of CBCT affects the diagnostic ability to detect the ERR. The results of the present study showed that the protocol with 0.3 voxel size was better than 0.15. Esterla et al reported that RR was detected in all the cases using CBCTimages;moreover, the lesions were bigger than 1−4 mm in 95.8% of the cases. The voxel resolution was 0.2 mm in that study, consistent with the present study.

Similar to the present study, Gabriela et al assessed the diagnostic capacity of CBCT with different voxel sizes in the detection of RR. They used three voxel sizes (0.2,0.3 and 0.4) and concluded that 0.3-mm voxel appeared to be the best; FOV in their study was the same(8), similar to the present study. In contrast with the present study, in a study by Dalili et al, small voxel resolutions (0.125−0.150mm) were better than large voxel resolutions (0.200−0.240 mm)(Dalili et al., 2012).

The FOV of the CBCT affects the diagnostic capacity. In a study by Sergio et al, the accuracy of CBCT in periimplant fenestration was assessed and it was shown that two voxel sizes did not affect fenestration detection and small FOV yielded better results than the large one, consistent with the present study. Dalili et al showed that larger FOV (6 inches) is better than small one (4 inches), contrary to the results of the present study. This difference might be due to differences in the sizes of cavities, FOVs and voxel resolutions between the two studies.

ALARA (As Low As Reasonably Achievable) should be considered when we want to select the radiographic device, although CBCT has the best diagnostic capacity for detecting the ERR compared with other devices. This image cannot be considered as routine imaging procedures in radiographic images in patients with external root resorption; only if there is suspected external root resorption with other imaging techniques, CBCT can be used to determine the exact extent of the resorption.

This study was an experimental study, in which round burs were used for the simulation of root resorption areas, and a spherical border line was created,although the normal border of root resorption is irregular.

Further studies or future clinical trials arerecommended in patients undergoing orthodontic treatment with external root resorption on a larger sample size and with more radiographic imaging protocol.

In conclusion, voxel size, FOV, multiple sections, size and location of the root resorption affect the diagnostic capacity. CBCT with 0.3-voxel resolution and smaller field of view showed high diagnostic accuracy.Sirona Dental Systems GmbH was more effective thanInc system when it was used in trans-axial views for small cavities located in the apical and middle thirds.

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