Vertical root fracture detection performance: Hybrid CBCT VS CBCT

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Abstract

Cone beam computed tomography (CBCT) has been wildly used in various disciplines of dentistry, including the endodontic task of investigating for vertical root fracture (VRF). Previously, CBCT systems were dominated by medium to a large field of view (FOV). As for high cost and large machine size, newly designed CBCT systems started to develop by combining them with digital panoramic radiography into one machine. These new models of the CBCT system were called hybrid CBCTs. This study aims to compare the difference in VRF detection performance using various FOV in hybrid CBCT and conventional CBCT units. Forty permanent mandibular premolar teeth were endodontically prepared and individually inserted into a dry human mandible. All teeth were scanned before and after induction of VRF using 4x4 and 8x8 cm FOVs. One observer randomly evaluated all radiographic datasets. Ten percent of samples were randomly selected for repeated observation with a two-week separation. The area under the receiver operating characteristic curve (AUC) for hybrid CBCT and conventional CBCT are 0.835 and 8.847, respectively. Slightly better detection ability with conventional CBCT is revealed. The smaller FOV and voxel sizes, the better VRF detection is observed in both machines. In conclusion, detection of VRF with hybrid CBCT might not be different from that in conventional CBCT systems, and smaller FOV might associates with higher detection ability.

Keywords: *CBCT; Field of view; FOV; Hybrid CBCT; Vertical root fracture*

1. Introduction

Vertical root fractures (VRF) are one of the most difficult clinical dilemmas to be diagnosed and treated. They have also been reported as the third most common cause of tooth loss after dental caries and periodontal disease (Garcia-Guerrero et al., 2018). Most VRFs occur in endodontically treated teeth and have similar symptoms to chronic apical periodontitis or chronic periodontitis (Huang & Lee, 2015). Due to its unspecific signs and symptoms, the diagnosis of VRF is difficult and often requires prediction rather than definitive identification (Khasnis et al., 2014). Eskandarloo and colleagues reported that direct visualization is the only procedure to confirm the presence of the VRF (Eskandarloo et al., 2016). Therefore, surgical exploration, including a full-thickness flap operation and direct examination of surrounding bony defect and root with high-magnification and illumination, is obliged (Cohen, Blanco & Berman, 2003). Nevertheless, this is quite an invasive method.

Conventional and digital 2-dimensional intraoral radiographs have been the most common modalities in detecting VRF in routine clinical practice (Kamburoglu et al., 2010). However, there are some limitations, as VRF can only be seen on the periapical radiographs when the central x-ray beam is parallel to the fracture line. Presentation of the radiolucent fracture line give the radiographic diagnosis of VRF, but an absence of these lines can occur due to superimposition of adjacent structures and give the false-negative diagnosis instead (Neves et al., 2014).

Since the cone beam computed tomography's introduction to dentistry, this technology offered 3-dimensional (3D) visualization, with high resolution and accurate information of hard tissues. Therefore, CBCT has been recognized as an important diagnostic tool with great potential for diagnostics, treatment planning and follow up in many dental fields within the past two decades. Thus CBCT has become a valuable imaging modality in dentistry and is increasingly employed (Willy, Dorothea & Bernd, 2010). As for VRF, limited field of view CBCT imaging has been declared by the American Association of Endodontics (AAE) as the imaging modality of choice for the diagnosis and management of the root fractures (Dutra et al., 2017).

The size of the imaging field of view (FOV) significantly affects the evolution of the CBCT scanner (Abramovitch & Rice, 2014). Initially, CBCT units were produced with limited ability to adjust the FOV and were dedicated as either full maxillofacial or small FOV units. As the CBCT market has matured, more CBCT units with a selection of various FOVs were also available (Scarfe et al., 2012). The CBCT unit can be grouped into three categories based on maximum vertical FOV (Flint & Casian Ruiz Velasco, 2017). A small or limited FOV covers approximately 5 cm diameter or less. It has the capability of high spatial resolution and is normally used for endodontic purposes. A medium FOV refers to an approximately 6 - 11 cm scans in height and covers one arch or both jaws. Normally, this type of scan is used for evaluation of the extent of a lesion, status of the temporomandibular joints, and implant planning cases. A large FOV is recommended for specific cases with skeletal anomaly/asymmetry and orthodontic/orthognathic surgery cases. The scanned area may range from 11 to 24 cm in height and covers most of the craniofacial skeleton.

Nowadays, the evolution of CBCT has created a new CBCT model, "hybrid CBCT" (Farman, 2009). This new CBCT system enfolds digital 2-dimensional (2D) dental imaging features such as panoramic radiograph or cephalometric radiograph and CBCT into the same unit with a relatively small to medium FOV. As a result, this new architecture offers space-saving and lower-cost investment (Dillenseger et al., 2016).

In VRF investigation, many studies have been studied about the detection accuracy among various modalities, such as conventional and digital periapical radiograph (PR) and comparing among each CBCT modality concerning exposure parameters, voxel size, and the influence of tooth orientation. However, to our knowledge, no study comparing hybrid and conventional CBCTs has been done before.

2. Objectives

This study aims to compare the difference in detection ability of the VRF between hybrid CBCT and conventional CBCT in 2 FOV sizes.

3. Materials and Methods

This study was conducted with approval from the Human research ethics committee of faculty of Dentistry, Chulalongkorn University (HREC-DCU 2019-030). Forty extracted human permanent mandibular premolars without 1% methylene blue detectable VRF were selected for this study. All teeth were stored in a 10% formalin solution soon after tooth extraction and kept moist in 10% formalin until VRF was induced. Only teeth with straight and single root canal were included, while teeth presented with previously root canal treated, root caries exposed pulp, root resorption, pulp calcification or canal obliteration, and incomplete root formation (open apex) were excluded.

3.1 Sample preparation

All teeth were cleaned by Gracy curette hand scaler to removed soft tissue debris and calculus and were decoronated using high-speed cylinder diamond bur at 2 mm above cementoenamel junction level to eliminate the bias of enamel fractures. The root canals were prepared with ProTaper NEXT rotary system (Dentsply Maillefer, Tulsa, OK) until reaching file size X3 (30/.07) and irrigated with distilled water.

3.2 Radiographic phantom preparation

A dry human mandible will be used as a radiographic phantom in this experiment to provided anatomical noise. The second premolar socket was carefully enlarged with a cylindrical bur to obtain a passive fit of the roots; then each sample was placed in this socket during the scan. Two pieces of 1.0 mm thick copper filters were attached to the x-ray window during image acquisition to simulate soft-tissue attenuation, as described by Jacobs et al. (2014).

3.3 Image scanning

CBCT images of each sample were acquired individually on a Veraviewepocs 3D R100 and 3D Accuitomo 170 (Morita Mfg Corp, Kyoto, Japan), which operated at 90 kVp and 5 mA. Two rounds of imaging were done before and after VRF fabrication (no-VRF and VRF groups). Two FOV scans on each machine were (4x4 and 8x8 cm) were performed. All 8x8 cm FOV dataset were undergone the second reconstruction process to resize the image volume down to only one sample without any change in voxel size. The manufacturer resolution settings for Veraviewepocs 3D R100 for both FOV were equal to 0.125 mm, while those for 3D Accuitomo 170 were 0.08 and 0.16 mm for small and medium FOV, respectively.

3.4 VRF fabrication

Each sample was temporarily fixed in 2 x 2.5 cm (diameter x height) PVC tube with resin acrylic. Then the artificial VRF was created using a universal testing machine (Hounsfield H10KM, test equipment Ltd, Redhill, United Kingdom) by insertion of a conical metal tip in the prepared root canal. A 10,000 N load-cell was applied with a compression speed of 10 mm/min, which was stopped once the applied force has dropped. VRF was inspected by direct visual and confirmed by micro CT.

3.5 Image analysis

Image analysis was performed using i-Dixel software with all tools (contrast & brightness adjustment, zoom, and volume rotation) available. One second-year master-degree student in oral and maxillofacial radiology program investigated the VRF in each sample in a low light environment with flat-screen monitors using 1920 x 1080 pixel resolution. Example images are shown in Figure 1.

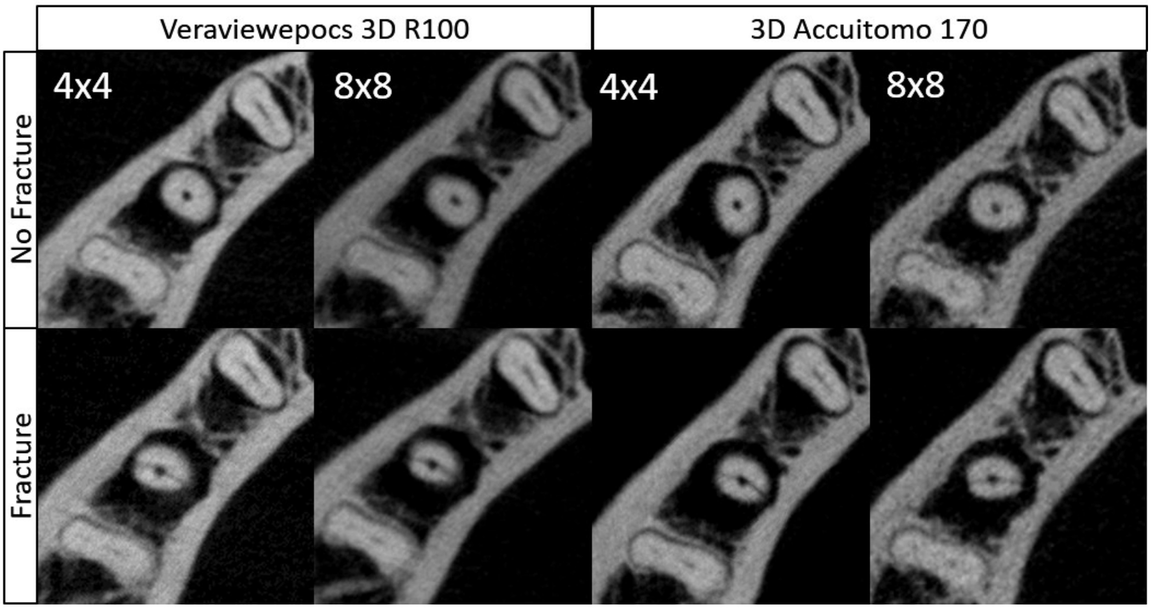

Figure 1 An example of an axial cross-section showing a vertical root fracture of hybrid CBCT (Veraviewepocs 3D R100) and CBCT (3D Accuitomo 170) using 4x4 and 8x8 cm FOV

The 5-point scoring system was used as followed:

1: Fracture definitely not present
2: Fracture probably not present
3: Uncertain
4: Fracture probably present
5: Fracture definitely present

If score 4 or 5 was recorded, the location of the fracture line was also assessed as B (buccal), M (mesial), D (distal), and L (lingual). Ten percent of the samples were repeatedly observed after two weeks.

3.6 Statistical analysis

The data was entered into SPSS software (version 22.0; IBM, Armonek, NY) and for dichotomized data: scores 1, 2, 3 as a negative finding (absence of fracture), and grouping scores 4 and 5 as a positive finding (presence of fracture). Cohen's kappa coefficient (k) was calculated for the degree of agreement in detecting VRF (intra-observer agreement). The k-values were interpreted as slight agreement (0.01 to 0.20), fair agreement (0.21 to 0.40), moderate agreement (0.41 to 0.60), substantial agreement (0.61 to 0.80) and almost perfect agreement (0.81 to 0.99). Receiver operating characteristic (ROC) analysis was performed to assess the relationship between the sensitivity and specificity of both CBCT machines and area under the curve (AUC) was calculated. Before calculation, all cases with scores 4 and 5 were rechecked for fracture location. Any case with the incorrect location was considered as incorrect detection of the VRF and converted from score 5 to score 1 or score 4 to score 2.

4. Results and Discussion

4.1 Intra-observer agreement

The intra-observer reproducibility is in perfect agreement for all datasets from 4x4 and 8x8 cm FOV of both hybrid and conventional CBCT units.

4.2 Detection performance of the vertical root fracture

AUC, sensitivity, and specificity were shown in Tables 1 & 2. Hybrid CBCT (Veraviewepocs 3D R100 CBCT) shows almost all slightly lower values than conventional CBCT (3D Accuitomo 170 CBCT). In exception, the 8x8 cm FOV in a hybrid unit provides a slightly higher value than the same FOV in a conventional machine. This peculiar performance is even better than the 4x4 cm FOV of the same unit in the high specification threshold region, as seen in Figure 2.

Table 1 Area under ROC curved showing diagnostic performance of hybrid CBCT and CBCT using 2 different FOVs

	AUC	SE		AUC	SE
Veraviewepocs 3D R100	0.835	0.033	3D Accuitomo 170	0.847	0.032
FOV of 4x4	0.849	0.044	FOV of 4x4	0.889	0.039
FOV of 8x8	0.822	0.048	FOV of 8x8	0.802	0.050

Table 2 Sensitivity and specificity in VRF detection with 4x4 and 8x8 cm FOV from hybrid CBCT and CBCT

	Sensitivity (%)	Specificity (%)		Sensitivity (%)	Specificity (%)
Veraviewepocs 3D R100	62.5	95.0	3D Accuitomo 170	63.8	96.3
FOV of 4x4	65.0	95.0	FOV of 4x4	67.5	100.0
FOV of 8x8	60.0	95.0	FOV of 8x8	60.0	92.5

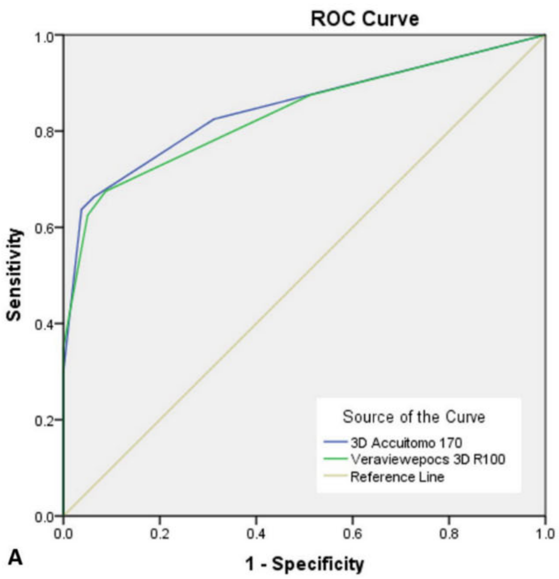

Figure 2 ROC curves for VRF detection performance at different sensitivity/specificity threshold by hybrid CBCT (Veraviewepocs 3D R100) and CBCT (3D Accuitomo 170) using 4x4 and 8x8 cm FOV

The 2-folded objectives of this study were to investigate the accuracy in detection of the VRF by using two different CBCT systems, including hybrid and conventional CBCTs and two scanning protocols, including FOV of 4x4 and 8x8 cm. Overall, CBCT performance in this study showed similar AUC to previous reports (Wanderley et al., 2017) using the same method of VRF induction. Despite the small number of an observer in this study, the result nonetheless can be applied or at least shows a trend of comparisons. However, studies with more observers are warranted for confirmation.

The slightly higher VRF detection accuracy from 3D Accuitomo 170 machine, which represents a conventional CBCT system than the Veraviewepocs 3D R100 unit, which represents a hybrid CBCT system in both FOVs is revealed. Accuracy of each CBCT system based on various factors such as exposure setting, detector type, FOV selection, and voxel size as well as system-specific image artifacts (Hassan et al., 2010). Because both Veraviewepocs 3D R100 and 3D Accuitomo 170 use the same exposure setting and same flat-panel detectors (FPDs), thus exposure setting and detector type did not affect in this study. Though, Katsumata et al. (2007) reported that FPDs were superior to image intensifier tube/charged coupled device (IIT/CCD) with lower image distortion, better spatial resolution, higher dynamic range, and reduction of noise and image artifacts. Kajan and Taromsari (2012) and Hassan et al. (2010) also reported that CBCT using FPDs is superior to other types in detecting the VRF.

FOV selection is usually directly related to the voxel size, which is the smallest element of the 3D volume (Farman & Scarfe, 2009). For higher accuracy in the diagnostic of the VRF, a smaller FOV and smaller corresponding voxel size was recommended (Huang & Lee, 2015). In the present study, using smaller FOV also showed slightly higher accuracy in detecting the VRF except for 8x8 cm FOV in hybrid CBCT systems. The explanation of this result may be due to differences in voxel size for each FOV selection. Veraviewepocs 3D R100 has the same voxel size of 0.125 mm for both FOVs, whereas 3D Accuitomo 170 had smaller voxel size in smaller FOV. However, Ozer (2011) reported that the voxel size of 0.125 mm and 0.2 mm had no significant differences in terms of sensitivity and specificity. In this study, the images using FOV of 8x8 cm were undergoing additional reconstruction to resize the overall image to a similar region of interest with the same voxel size. As a result, the final dataset seems to be magnified, and this appearance might result in an increase in noise. Hence, image interpretation of the VRF might be affected.

The numbers of basis images are directly related to the amount of information generated for image reconstruction. A greater number of basis images provide more information in image reconstruction and results in smoother images and less noise and artifacts (Scarfe & Farman, 2008), which could be another reason that 3D Accuitomo 170 with 360º of rotation and 577 basis images per scan had better accuracy compared to Veraviewepocs 3D R100 with 180º of rotation and 367 basis images per scan. Nevertheless, a larger number of basis images will increase the scanning time, longer reconstruction time, higher radiation dose to the patient (Wanderley et al., 2017).

5. Conclusion

This study, deriving from one observer using the ex vivo VRF model, demonstrated that the abilities of hybrid CBCT and CBCT in detecting VRF might be similar. Although the CBCT shows a slightly higher performance, FOV and voxel size selection might affect the VRF investigation. With smaller FOV and voxel size, better VRF detection might be achieved. Further research is required.

6. Acknowledgments

This study is supported by the Department of Radiology, Faculty of Dentistry, Chulalongkorn University for the use of equipment in this research project. The authors also deny any conflicts of interest related to this study.

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