CORRELATION OF FRACTURE WIDTHS

DETECTED ON CBCT

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

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ABSTRACT

CORRELATION OF FRACTURE WIDTHS DETECTED ON CBCT
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Introduction: A vertical root fracture (VRF) is defined as fractured root segments that are incompletely separated. The introduction of 3-dimensional cone beam computed tomography (CBCT) represents a significant advancement in dental imaging, enabling clinicians to view areas of interest in multiple planes. The width of VRFs have been measured using various instruments, however, no previous research has utilized digital microscopy in measuring VRF widths. There is limited research correlating fracture width with the ability to detect VRF radiographically. **Objective**: To measure the fracture widths of previously evaluated teeth and determine if the width influences the ability to detect VRFs on CBCT. **Materials and Methods**: 26 fractured teeth, evaluated in a previous study, were analyzed. Two samples were lost to complete fracture, leaving 24 teeth with VRF for analysis. In the previous, unpublished NPDS study, board certified specialists reviewed CBCT scans and identified the samples as “definitely fractured,” “uncertain,” or “definitely not fractured.” The current study measured fractures with a Hirox digital microscope (Hirox, KH 7700) utilizing a methodology previously established. The Hirox measurement tool (Hirox, KH 7700 software) was used to record 3 measurements in the apical, middle, and coronal thirds (9 total) of each specimen. The average of the 3 measurements in each third determined the fracture width. This data were compared to the previous study’s data and correlated with the ability to detect the fracture radiographically. Data were analyzed using descriptive statistics and logistic regression. **Results**: Mean widths of the VRFs ranged from 24.45-129.52µm. Correlating the results with the previous study, 44.07µm was the fracture width at which examiners were more likely to detect a fracture radiographically. **Conclusion**: Analysis revealed VRF’s wider than 44µm are more likely to be identified on limited FOV CBCT images.

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I. INTRODUCTION

A vertical root fracture (VRF) is defined as fracture where the root segments of a tooth remain incompletely separated. It may occur in a bucco-lingual or mesio-distal direction and induce formation of an isolated bony defect or sinus tract (1) which may be the first indication of VRF (2). Other diagnostic signs may include tooth mobility or sensitivity to percussion and/or palpation (3). However, the onset of clinical signs or symptoms of VRF may be delayed or totally absent. In cases of iatrogenic VRFs, the time between root canal treatment and evidence of symptoms was reported to range from 3 days to 14 years with an average of 40 months (3). In addition to localized periodontal disease, symptoms of VRF may mimic those of endodontic failure with patient complaints ranging from mild to extreme discomfort (4). A classic study by Meister, et al, (3) revealed 65% of subjects with VRF had mild pain, 6% severe pain, 28% were asymptomatic while 28% presented with an abscess.

Radiographic identification of a VRF may be difficult, if not impossible for clinicians to determine. Rud and Omnell (5) demonstrated these fractures could only be detected if the x-ray beam fell within 8°, 4° on either side, of the fracture. A VRF on periapical radiographs may appear as a diffuse widening of the periodontal ligament space of the involved root. Other traditional radiographic indicators include; a periapical radiolucency, bone loss or visible separation of the root segments (4). The introduction of 3-dimensional cone beam computed tomography (CBCT) has been a significant advancement in dental imaging. CBCT enables the clinician to easily view areas of interest on multiple planes compared with conventional 2-dimensional radiography (6). Fayad, et al, (7) described the presentation of VRF on CBCT to include; bone loss in the mid-root area with intact bone coronal and apical to the defect, the absence of buccal or lingual bone, a radiolucency surrounding the root where a post terminates, a space between the cortical plate and root surface, and finally, visualization of the fracture on a slice of the CBCT image. Despite the advantages, CBCT has limitations. High cost and low portability limit its accessibility and there is also concern over the increased radiation exposure for patients. Image resolution is in the range of 2 line pairs (lp)/mm whereas conventional film and digital radiography average 12-20 lp/mm (8). CBCT images loose resolution when they are magnified. Image artifacts such as beam hardening, streaking and cupping can limit the clinician's ability to detect fractures if they appear in the region of diagnostic interest (9). This, along with a lack of high resolution scans, can make visualizing a VRF difficult on CBCT.

A number of investigators have employed different methodologies to measure the size of fractures in extracted human teeth. Schwarz, et al(10) used scanning electron microscopy, Brady, et al (11) utilized optical coherence tomography while Huang, et al (12) used micro computed tomography to measure the widths of VRFs. Digital microscopy has been utilized in dentistry to evaluate tooth area and intercuspal distances (13) and to measure marginal and internal discrepancies of dental prostheses (14). However, no published study has incorporated this technology as a measurement tool for evaluating fractured teeth. Therefore, this Walter Reed National Military Medical Center Institutional Review Board Board approved investigation used digital microscopy to correlate tooth fracture widths of previously analyzed CBCT scans of teeth with VRFs.

II. MATERIALS AND METHODS

In a previous unpublished study conducted at the Naval Postgraduate Dental School, McMurray et al evaluated the ability of examiners to detect VRFs on limited field of view (FOV) CBCT scans. Two Board Certified Endodontists and a Board Certified Oral and Maxillofacial Radiologist randomly reviewed the scans scoring each specimen as definitely fractured (DF), uncertain (U), or definitely not fractured (DNF) (Table 1, columns 1-4).

For this study, the previous examiners results were dichotomized by establishing a consensus of either fractured (F) or not fractured (NF) for each of the 26 fractured specimens (Table 1, column 5). To measure individual fracture widths, specimens were positioned on the stage of a digital microscope (KH-7700, Hirox-USA, Inc.) and stabilized using rope wax. Viewing was facilitated by rotating the lens body 5-15° off the perpendicular axis and complementing the system's through the lens lighting system with an additional light source (Opelco, Optical Elements Corporation). A high performance zoom lense (MXG-5040RZ, Hirox-USA, Inc.) at 250X/1156.74 μm field (Figure 2) was used to view and capture images of the apical, middle and coronal thirds of each specimen. Three fracture width measurements were recorded in each third using the 2D line measurement tool (KH 7700 software, Hirox-USA, Inc.). A mean of the 9 measurements was calculated to serve as the specimen's fracture width estimate (Figure 3, Table 1 column 6). Data were analyzed using descriptive statistics and regression analysis.

III. RESULTS

From the cohort data of the 26 fractured teeth, it was established by consensus that 16 of the specimens were correctly identified as fractured while 10 were incorrectly identified and non-fractured on the previously reviewed limited FOV CBCT scans. Of the 26 teeth analyzed, 2 were lost to complete fracture. The mean widths of the VRFs of the remaining 24 teeth ranged from 24.45µm to 129µm. Within the limits of this data, examiners were able to detect fractures as small as 24.99µm on the CBCT scans. Conversely, a fracture as large as 69.43µm went undetected. The dichotomized data were analyzed using logistic regression. The ability to detect (1.00), or not detect the fractures (0.00), was plotted against mean fracture widths (Figure 4). The intersection of the logistic regression equation and the 0.50 proportion of fractures detected was used to establish a mean fracture width examiners were more or less likely to identify a VRF on limited FOV CBCT scans. This value was 44.07µm. Two samples with mean fracture widths of 54.99µm and 69.43µm were identified as NF by the examiners, while three fractures with mean widths of 24.99µm, 33.97µm and 37.96µm were identified as being fractured by the examiners.

IV. DISCUSSION

Clinical and radiographic detection of VRF can be problematic due to a lack of specific signs and symptoms. Radiographic detection is difficult if the x-ray beam is more than 4 degrees on either side of the fracture or if there is not complete separation of the segments (5). Often, a definitive diagnosis can only be made following direct visualization of the suspected fracture (15). However, once identified, a VRF complicates treatment and the prognosis for these teeth is unfavorable. Since there are currently no reliable methods for treatment, (16) VRF frequently leads to tooth loss. For this reason, an accurate diagnosis of VRF is critical to minimize the unnecessary extraction of an otherwise treatable tooth.

Recent studies have evaluated the ability of periapical radiographs and CBCT to detect VRF, but reach different conclusions. A systematic review by Chang, et al, (17) reported insufficient evidence for CBCT to reliably detect VRFs. Chavda (18) arrived at a similar conclusion when comparing CBCT and digital radiography. Other authors have shown that CBCT is accurate in detecting VRF and that voxel size is not important (19,20).

Past studies have used different CBCT scanners and voxel sizes to investigate the ability to detect fractures using CBCT. Brady, et al (11) used 2 CBCT units with 2 different voxel sizes, the 3D Accuitomo (J. Morita Mfg. Corp.) with a voxel of 0.08mm^3 and the i-CAT (Imaging Sciences International) with a voxel of 0.125mm^3. Fracture widths in their study ranged from 30-110μm, and concluded that CBCT was significantly more accurate in detecting fracture sizes greater than 50μm. Additionally, the 3D Accuitomo was significantly more accurate than the i-CAT in detecting fractures <50μm due to its smaller voxel size. A study by Makeeva, et al (21) using a novel *in vitro* and *in vivo* method evaluated extracted teeth with induced VRFs ranging in widths from 20-300μm. The specimens were scanned with the 3D

Accuitomo using a voxel size of $0.16mm^3$. Fractures <50μm were excluded because they did not extend completely through the radicular dentin leaving 2 groups of specimens consisting of fractures 50-150μm and fractures >150μm. They concluded the in vitro accuracy of CBCT for fractures 50-300μm was 81%, while in vivo accuracy was 60%. This study also noted that detection of VRF depended on the width of the fractures (21).

The voxel size of the Kodak Carestream 9000 (Carestream Health, Inc.) used in this study was $0.076mm^3$, which was smaller than used in the previously mentioned studies. This could explain why smaller fractures were detected in the present investigation. There were two fractures larger than 44.07μm not identified by the examiners. Partial volume averaging (PVA) could be one of the reasons for this finding. Partial Volume Averaging occurs when the voxel is greater than the object being imaged. In this case the voxel is not representative of the object. Instead, it is a weighted average of the different values. Partial Volume Averaging can also occur in areas that have exaggerated changes in the z-axis (9). In the present study, as well as others, fractures may have been detected as a contiguous plane of pixels with a lower radio-density than the surrounding dentin (8, 9,). The specimens in this study were scanned in a model of the mandible. As a result, no osseous or pathologic indicators that are commonly seen *in vivo* indicative of a VRF were present. The experience level of the examiners also has to be taken into account when viewing and interpreting CBCT images (22). This could play a role in the ability to accurately recognize and diagnose a VRF.

Three specimens with fracture widths smaller than 44μm were identified as fractured by the examiners. The samples used consisted of anterior and premolar single rooted teeth. In the scans, there may have been overlap of external anatomy such as a mesial groove. Accessory canals, lateral canals or other internal anatomy may have enhanced the radiolucency in the area of the fracture. All of these variables may have an effect on whether or not the fractures are visualized.

V. CONCLUSION

Root fractures not visualized radiographically can only be definitively diagnosed through direct visualization of the root (13). Therefore, an accurate diagnosis for VRF is necessary to prevent unnecessary surgery or extraction of otherwise healthy teeth. CBCT may provide the clinician with a reliable means to correctly diagnose a VRF, providing the smallest voxel size is used. In this study fracture widths ranged from 24 to 129 micrometers. Those fractures greater than 44 micrometers were more likely to be identified on limited FOV CBCT images.

FIGURES

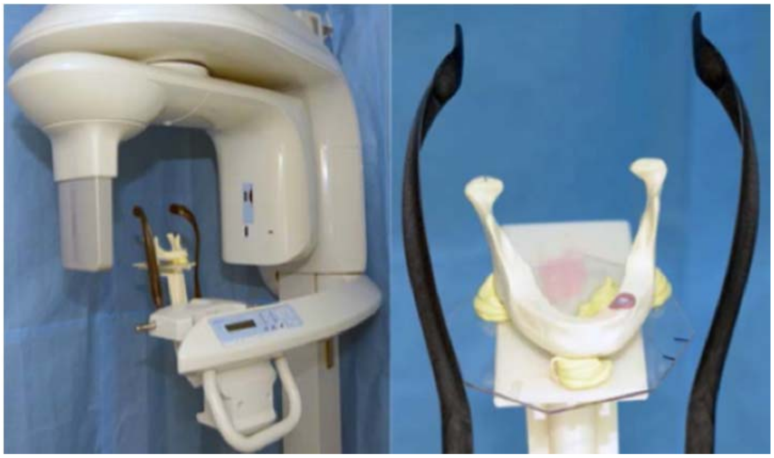

Figure 1. A limited FOV CBCT was used to capture scans of extracted teeth positioned in the left premolar region of an artificial mandible.

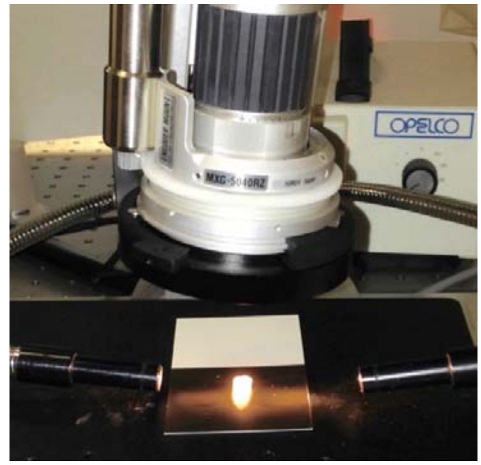

Figure 2. A specimen prepared for imaging using digital microscopy.

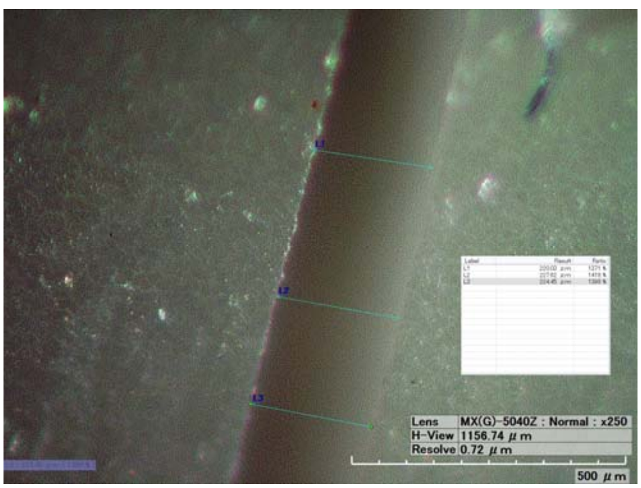

Figure 3. Measurements of fracture width. Three measurements were taken in each region.

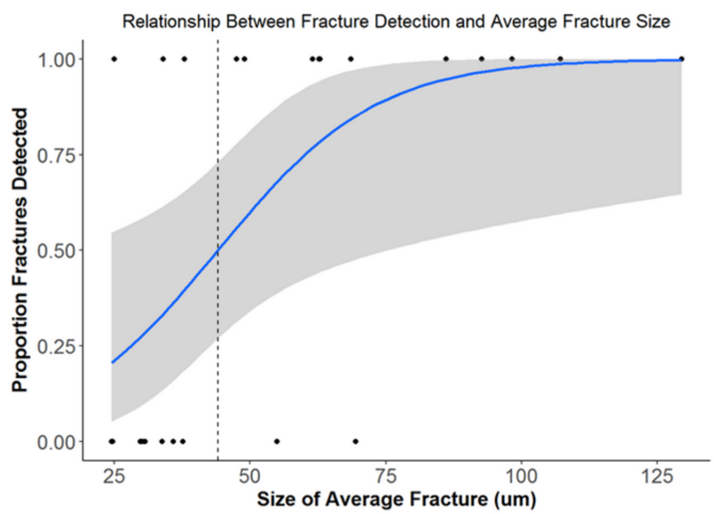

Figure 4. Logistic regression analysis was used to establish a relationship between the ability to detect a fracture and mean fracture widths. The intersection of the logistic regression function and a perpendicular to the mean fracture width (dashed line) corresponds to 44.07μm.

TABLE

Specimen #	Examiner 1	Examiner 2	Examiner 3	Consensus	Mean Width (μm)
27	DF	DF	DF	F	129.5
4	DF	DF	DF	F	107.2
41	DF	U	DF	F	98.3
35	DF	DF	DF	F	92.7
19	DF	DF	DF	F	86.1
9	DNF	DNF	DNF	NF	69.4
51	DF	DF	DF	F	68.6
50	DF	DF	DF	F	62.9
45	DF	DF	DF	F	62.7
47	DF	DF	DF	F	61.5
13	DNF	DNF	DF	NF	54.9
26	DF	DF	DF	F	48.9
28	DF	DF	DF	F	47.5
17	DF	DF	DF	F	37.9
29	U	DNF	DF	NF	37.6
25	DNF	DNF	DNF	NF	35.8
30	DNF	DF	DF	F	33.9
12	U	DNF	DNF	NF	33.8
5	DNF	DNF	DNF	NF	30.7
43	DNF	DNF	DF	NF	30.2
11	U	U	DNF	NF	29.6
15	DNF	DF	DF	F	24.9
44	DNF	DNF	DNF	NF	24.7
21	DNF	DF	DNF	NF	24.5
8	DF	DF	DF	F	
31	DF	DF	DF	F	

DF=Definitely Fractured, DNF=Definitely not Fractures, U=Uncertain
F=Fractured, NF=Not Fractured

Table 1. Data from 26 fractured specimens indicating responses of the 3 examiners from a previous study conducted at the Naval Postgraduate Dental School (columns 1-4). For this study, examiner data was dichomizated (column 5) and mean fracture widths of the specimens measured using digital microscopy

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