Comparison of Endodontic Treatment Planning

with CBCT and Periapical Radiography

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THESIS

Submitted as partial fulfillment of the requirements
For the degree of Master of Science in Oral Sciences
In the Graduate College of the
University of Illinois at Chicago, 2012

Chicago, Illinois

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This thesis is dedicated to my late grandfather Henry Liu whose hard work and dedication was an inspiration throughout my life.
ACKNOWLEDGEMENTS

I would like to thank Dr. Bradford Johnson for his continued guidance and support. I am extremely grateful to Dr. Mohamed Fayad for his inspiration and advice. I am fortunate enough to have Dr. Richard Monahan to lend me his assistance in this project. I would also like to thank Dr. Robert Goldberg and Dr. Paul Ashkenaz for their involvement in my research. Finally I would like to thank Dr. Logan Bell for his assistance with statistical analysis, and Blanca Sanchez for her general assistance.

JE
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>A. Background</td>
<td>1</td>
</tr>
<tr>
<td>B. Statement of Problem</td>
<td>1</td>
</tr>
<tr>
<td>C. Purpose of Study</td>
<td>2</td>
</tr>
<tr>
<td>D. Significance of Problem</td>
<td>3</td>
</tr>
<tr>
<td>E. Significance of Study</td>
<td>3</td>
</tr>
<tr>
<td>II. CONCEPTUAL FRAMEWORK AND RELATED LITERATURE</td>
<td>5</td>
</tr>
<tr>
<td>A. Conventional Periapical Radiographs</td>
<td>5</td>
</tr>
<tr>
<td>B. Medical CT</td>
<td>6</td>
</tr>
<tr>
<td>C. Cone-Beam Computed Tomography</td>
<td>6</td>
</tr>
<tr>
<td>1. Overview</td>
<td>6</td>
</tr>
<tr>
<td>2. Diagnosis of Apical Periodontitis</td>
<td>8</td>
</tr>
<tr>
<td>3. Treatment Planning of Endodontic Surgery</td>
<td>9</td>
</tr>
<tr>
<td>4. Diagnosis of External Inflammatory Root Resorption</td>
<td>10</td>
</tr>
<tr>
<td>5. Diagnosis of Internal Inflammatory Root Resorption</td>
<td>11</td>
</tr>
<tr>
<td>6. Diagnosis of Root Fractures</td>
<td>12</td>
</tr>
<tr>
<td>7. Review of related literature</td>
<td>13</td>
</tr>
<tr>
<td>III. METHODS</td>
<td>14</td>
</tr>
<tr>
<td>A. STEP 1: Case Selection</td>
<td>14</td>
</tr>
<tr>
<td>B. STEP 2: Radiograph Diagnosis</td>
<td>15</td>
</tr>
<tr>
<td>C. STEP 3: Radiograph Treatment Plan</td>
<td>16</td>
</tr>
<tr>
<td>D. STEP 4: CBCT Diagnosis and Treatment Plan</td>
<td>17</td>
</tr>
<tr>
<td>E. STEP 5: Data Analysis and Comparison of Treatment Plans</td>
<td>17</td>
</tr>
<tr>
<td>1. Descriptive Statistics</td>
<td>18</td>
</tr>
<tr>
<td>2. Chi-Square Test</td>
<td>19</td>
</tr>
<tr>
<td>IV. RESULTS</td>
<td>20</td>
</tr>
<tr>
<td>A. Collection of data</td>
<td>20</td>
</tr>
<tr>
<td>B. Comparison between gold standard and radiographs</td>
<td>20</td>
</tr>
<tr>
<td>C. Comparison between gold standard and CBCT scans</td>
<td>21</td>
</tr>
<tr>
<td>D. Comparison between radiographs and CBCT to gold standard diagnosis</td>
<td>22</td>
</tr>
<tr>
<td>E. Treatment plan changes between radiographs and CBCT</td>
<td>23</td>
</tr>
<tr>
<td>F. Chi-Square Test</td>
<td>24</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS (continued)

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. DISCUSSION</td>
<td>25</td>
</tr>
<tr>
<td>A. Limitations of Study</td>
<td>25</td>
</tr>
<tr>
<td>B. Implications for clinical practice</td>
<td>27</td>
</tr>
<tr>
<td>C. Future Studies</td>
<td>28</td>
</tr>
<tr>
<td>VI. CONCLUSION</td>
<td>29</td>
</tr>
<tr>
<td>CITED LITERATURE</td>
<td>30</td>
</tr>
<tr>
<td>VITA</td>
<td>35</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Radiographs to Gold Standard Comparison</td>
<td>21</td>
</tr>
<tr>
<td>II. CBCT to Gold Standard Positive Comparison</td>
<td>22</td>
</tr>
<tr>
<td>III. Comparison between radiographs, CBCT and gold standard diagnosis</td>
<td>23</td>
</tr>
<tr>
<td>IV. Treatment plans changed between radiographs and CBCT</td>
<td>24</td>
</tr>
</tbody>
</table>
Accurate and confident treatment planning is an essential part of endodontology. Diagnostic imaging helps the clinician to visualize the dental anatomy in areas that cannot be seen clinically. For years, periapical radiographs have been used as an adjunct to help endodontists diagnose pathology and aid the clinician in developing a treatment strategy. Recently a new imaging modality, cone-beam computed tomography (CBCT), has been introduced in the market and has been found to be useful in a number of applications. The diagnostic yield of CBCT images is said to be superior compared to periapical radiographs (PA) and the information gained by these scans has proven to be valuable in clinical treatment planning and decision making.

We will investigate whether a preoperative CBCT significantly changes treatment decisions from a preoperative PA radiograph. The aims of this study are to determine whether or not additional useful information can be obtained by CBCT and if that additional information can be used to improve treatment planning. Thirty endodontic cases taken from a private practice endodontic office were chosen randomly to be included in this study. Each case was required to have a preoperative digital PA radiograph as well as a preoperative CBCT volume of the same tooth. Three board certified endodontists were then shown the 30 preoperative radiographs and asked to choose from a list a preliminary diagnosis and a preliminary treatment plan based on that diagnosis. Two weeks later the same endodontists were shown the 30 preoperative CBCT volumes and again asked to choose from the same list a preliminary diagnosis and a preliminary
treatment plan based on that diagnosis. Their treatment planning choices were then compared to see if there was a change from the radiograph to the CBCT volumes.

A modification in each examiner’s treatment plan, between the two imaging modalities was recorded in 19 out of 30 cases (63.3\%(P=0.001), 17 out of 30 cases (56.6\%(P=0.012), and 20 out of 30 cases (66.7\%(P=0.008).

We conclude that a preoperative CBCT volume provides information capable of modifying a clinician’s treatment plan from a preoperative PA radiograph on average 62.2\% of the time, within the confines of this study.
I. INTRODUCTION

A. Background

In endodontology, clinical examination, and diagnostic imaging are essential components of the preoperative diagnosis (1). Accurate diagnostic imaging supports the clinical diagnosis and allows the clinician to better visualize the area in question. Conventional two-dimensional radiographs provide clinicians with a cost effective, high-resolution imaging modality, which continues to be the most popular method of imaging today. However, periapical (PA) radiographs have limitations in their diagnostic potential. Information is difficult to interpret especially when the anatomy and background pattern is complex (2). Cone Beam Computed Tomography (CBCT) is a diagnostic imaging modality, which gives a three-dimensional image of the maxillofacial region. CBCT is capable of providing images at a low radiation dose and with sufficient spatial resolution for applications in endodontic diagnosis and treatment planning. Furthermore, CBCT overcomes many limitations that conventional radiography encounters such as early detection of invasive cervical resorption lesions (3) and three-dimensional evaluation of the root canals and surrounding anatomy.

B. Statement of Problem

Diagnostic information directly influences treatment planning and clinical decisions. Accurate data leads to better treatment decisions and potentially more predictable outcomes (4). While conventional PA radiography has been used for many years as a diagnostic aid in
endodontics, some studies now demonstrate the inferiority of PA radiographs in detecting pathology when compared to CBCT (5). CBCT has been successfully used in endodontics (4,6,7) and there have been many studies acknowledging the technical advantages of CBCT over conventional radiographs. However, studies that show preoperative information from CBCT and its affect on treatment planning don’t exist. There has been considerable debate regarding whether or not CBCT should be used as a standard preoperative imaging modality compared to standard PA and bitewing radiographs. The majority of the opposition to standard preoperative CBCT imaging relates to the additional ionizing radiation. The effective radiation dose to patients when using CBCT is higher than conventional radiography and the benefit to the patient should outweigh any potential risks of the procedure in order to be justified (8). Radiation dose should be kept as low as reasonably achievable (ALARA). The decision as to if the benefits of CBCT outweigh the potential risks should be judged on an individual basis (9). Endodontic problems occur when you least expect them, and the use of CBCT should not be used to detect things we know are there, but to see what we don’t know is there. Its effective role in treatment planning has not been investigated. It is therefore important to determine if the information gained by CBCT on endodontic cases really does alter a clinician’s treatment plan and the way operators approach endodontic pathology.

C. **Purpose of Study**

The purpose of this study was to evaluate if CBCT images provide more information than standard PA radiography to the degree that practitioners change their treatment plan when and if they see additional information. We will investigate whether a preoperative CBCT significantly
changes treatment decisions compared to a preoperative PA radiograph. The null hypothesis is that a preoperative CBCT image does not significantly change an operator’s proposed treatment plan from a preoperative PA radiograph. The aims of this study are 1: To evaluate which imaging modality gives more preoperative information: CBCT or PA radiographs, 2: if the additional information can be used to improve treatment planning, 3. To assess which imaging modality offers higher benefits to the patient and clinician.

D. Significance of Problem

The problem of incorrect, delayed or inadequate endodontic treatment planning not only places the patient at risk, but could result in unnecessary or inappropriate endodontic treatment. Two dimensional PA radiographs reveal a limited amount of information that may lead the clinician to misdiagnose or overlook potential pathology. For these reasons, endodontic treatment planning based on conventional two-dimensional PA radiographs alone may be inadequate for optimal endodontic treatment planning.

E. Significance of Study

The significance of this study is to compare CBCT to digital PA radiography in endodontic treatment planning. The ability to determine whether this imaging modality allows the clinician to more accurately diagnose and treatment plan allows for more efficient and accurate treatment to be carried out. It is our hope that additional information such as presence of resorption, fractures, periapical pathology and other discoveries may alter the treatment plan
compared to the one developed using only PA radiographs. Additional information gained by CBCT may be significant enough to change the existing treatment plan created from the information gained by standard radiographs.
II. CONCEPTUAL FRAMEWORK AND RELATED LITERATURE

A. Conventional periapical radiographs

Over many years there have been a number of different imaging techniques utilized in dentistry. Some of these include Tuned Aperture Computed Tomography (TACT), Magnetic Resonance Imaging (MRI), Ultrasound, Computed Tomography (CT), Cone beam computed tomography (CBCT), and conventional radiography.

Intraoral PA radiographs are still the most commonly used imaging technique for endodontic procedures, providing important information on anatomy and pathology. Despite their long history and widespread use, PA radiography yields limited information for a number of reasons. They compress three-dimensional anatomy, create geometric distortion and anatomical noise, and are ultimately limited by the fact that information is rendered in only two dimensions. Interpreting radiographs is also difficult when roots of teeth overlap and anatomical structures are present. Dental materials such as crowns, posts, and filling materials may also add additional difficulty in interpreting the radiograph (10). In addition to these technical limitations, the major reason for advancing to another imaging modality is the clinical limitations. Two-dimensional radiographs don’t adequately demonstrate pathology in the buccal-lingual dimension. The clinician has to make decisions based on a 2-D image for a 3-D tooth. Their sensitivity doesn’t demonstrate pathology until it has advanced a significant degree into hard tissues. Finally, they are limited in their ability to provide accurate measurements, anatomy and
locations of key structures. For all these clinical limitations, new imaging techniques have been introduced into clinical endodontics.

B. **Medical CT**

The use of computed tomography (CT) scans has enabled evaluation of the true extent of lesions and their spatial relationship to important anatomical landmarks (11). Detection of periapical lesions by CT scans has also been shown to be more effective than conventional radiography (12,13). Furthermore, CT scans were able to detect more furcal defects than PA radiographs in upper molars (14). Huumonen et al (13) concluded that CT scans may provide information important for retreatment decisions, especially in the case of apical surgery. Despite these advantages, CT scans are expensive and produce much higher radiation doses to the patient that PA radiography. Also, lengthy scanning times and the size of the machine make them impractical for the majority of dental applications.

C. **Cone-Beam computed tomography (CBCT)**

1. **Overview**

Recently, cone-beam computed tomography (CBCT) has been introduced for dental offices because of the reduced costs and size (15,16). The scans produced by a CBCT imaging system have a significantly reduced scan time, reduced cost for the patient, and use a lower radiation dose than medical CT (17,18). Different CBCT machines will have different radiation doses determined by the particular brand, settings, and the area of the mouth to be scanned. The
3-D imaging software utilized with the CBCT allows the clinician to view the entire volume and see the axial, coronal and sagittal 2-D sections. These are extremely valuable because some of these views are not obtained with PA radiography. Furthermore, modern software is able to create a 3-D reconstruction of the area, which further helps the clinician visualize the area of interest.

CBCT’s utilize a smaller, limited field of view along with a high spatial resolution in all planes (19,20,21). They can be classified into two categories based on the machines field of scan or field of view (FOV). A limited CBCT is more often utilized for endodontic purposes while a full CBCT is more suited for ortho or facial scans. The FOV of limited CBCT ranges from 40-100 mm, while the FOV of full CBCT ranges from 100-200mm (4). Apart from the FOV, another difference is that the resolution is generally higher for the limited FOV machines. Resolutions of CBCT images are measured by voxel sizes. A voxel is a series of 3-D pixels, which comprise the volume image. Unlike pixels, voxels are isotropic, which enables objects within the volume to be accurately measured in different planes. Voxel size is important in terms of quality and scanning times of CBCT volumes.

CBCT has many advantages over conventional radiography for endodontic uses. More and more applications are being identified as the technology is being more readily utilized. Potential endodontic applications include diagnosis of periapical pathology (22,23), measurement of internal and external resorption lesions (24), identification of perforations, fractures and trauma(25), and pre-surgical treatment planning (26).
2. **Diagnosis of Apical Periodontitis**

Historically, PA radiographs are used clinically to diagnose apical periodontitis. Radiographic success after root canal treatment is determined when the periapical radiolucency is absent after treatment. However, a periapical radiograph is a two-dimensional view of a three-dimensional object. Periapical lesions confined within the cancellous bone are often not detected (27,28,29). A lesion of a certain size can be detected in an area with a thin cortex, while the same lesion may not be detected in a region with a thicker cortex (30). CBCT scans enable radiolucent endodontic lesions to be detected before they would be apparent on conventional PA radiographs. Lofthag-Hansen et al (31) compared the periapical status of 46 posterior mandibular and maxillary teeth using CBCT scans and two angled periapical radiographs. CBCT allowed 38% more periapical lesions to be detected than with conventional radiography. Another study by Soğur et al (32) shows that the combination of 2 PA radiographs instead of 1 did not significantly increase the accuracy of conventional radiographs over the CBCT scans. Estrela et al (33) compared the diagnostic accuracy of panoramic and periapical radiographs with CBCT for the detection of apical periodontitis. They found post-treatment apical periodontitis in 35% of teeth using periapical radiographs, but in 63% using CBCT scans. Low et al assessed the apical condition of 37 premolars and 37 molars in the maxilla (156 total roots) using periapical radiographs and CBCT scans. They found that the CBCT scans demonstrated significantly more lesions (34%) than conventional radiography. Stavropoulous et al (22), showed that CBCT has a higher sensitivity and diagnostic accuracy than conventional radiography when evaluating the presence of artificially created bone defects. These findings show that the absence of a periapical lesion on conventional radiographs does not necessarily guarantee that there is not a lesion present and that a CBCT scan is more accurate at diagnosing these lesions. The prognosis
of root canal treatment is more successful when teeth are treated before more apparent radiographic periapical pathology is detected (34). Therefore, the use of CBCT for early detection of periapical pathology may yield a higher success rate and more efficient management of endodontic cases. The generally higher detection rates afforded by CBCT may also be of clinical importance in patients who present with pain or who have poorly localized symptoms with no evidence of pathology that can be seen by conventional radiography.

3. **Treatment Planning of Endodontic Surgery**

CBCT has been recommended for the planning of endodontic surgery (26). The three-dimensional imaging allows accurate assessment of the location of the lesion, anatomical position of the root apices, and the proximity of vital structures including the inferior alveolar nerve, mental foramen, maxillary sinus, and nasal cavities (35,36,37). Rigolone et al. (26) described the value of CBCT in planning for endodontic surgery. They used CBCT to assess the horizontal distance from the buccal cortical plate to the palatal root. They imaged 43 maxillary first molars on 31 patients referred for retreatment and measured the mean distance of the palatal root from the external vestibular cortex (mean; 9.73 mm). They also found that the frequency of the maxillary sinus to lay between the buccal and palatal roots was 25%. They concluded that CBCT may play an important role in optimizing palatal root apicoectomy via directing surgery through vestibular access. Velvart et al (12) found that CT scans aided in determining the relationship of PA lesions to the mandibular canal before periapical surgery. The information gathered cannot only aid in surgical planning, but also in determining case prognosis. Hopeless root fractures and root resorptions can be detected without exploratory surgery (38), which can save both time and unnecessary treatment. A case report by Cotton et al (4) provided a good
example of locating the inferior alveolar nerve and mental foramen in relation to the apex of a mandibular premolar. The CBCT allowed for superior visualization of extruded sealer, which could be putting pressure on the neurovascular bundle, resulting in the symptoms. The CBCT allowed for the assessment of critical anatomy, extruded material, and the root end of the right mandibular second premolar with its proximity to the mental nerve.

4. **Diagnosis of External Inflammatory Root Resorption**

CBCT has been implicated as a reliable and valid method of detecting external inflammatory root resorption and performs significantly better than intraoral PA radiography (3). Because treatment of resorption can be very complex and unpredictable, accurate imaging is important to the diagnosis and treatment plan. The diagnosis of resorption is usually based upon the radiographic examination (39). External inflammatory resorption (EIR) can be characterized radiographically by dome-shaped radiolucent lesions along a root surface (40). Gartner et al (41) also described the radiographic features of internal and external resorption. Taking multiple angled radiographs have proven useful in distinguishing these entities. However, conventional radiographs don’t provide a true and full representation of the lesion, especially in the buccal-lingual direction. They are unable to identify the true extent, location or the portal of entry of a resorptive lesion (4). Studies have demonstrated that conventional intraoral radiography is not a reliable technique for detecting external root resorption in its early stages (39,42). Invasive cervical resorption (ICR) is often misdiagnosed as internal resorption; therefore identification of the portal of entry is critical (43). Because EIR can advance rapidly, clinical treatment must be initiated as promptly as possible (44). The earlier the resorption is diagnosed and treated the better the prognosis is for the tooth. The limitations of conventional radiographs could result in
the late diagnosis of external inflammatory root resorption, which may result in tooth loss. CBCT overcomes these shortcomings and provides a reliable and valid method of detecting artificially created external inflammatory root resorption defects (3). A case study by Cotton et al (4) demonstrated that a CBCT scan identified the size, location, portal of entry and the exact subossesous extent of the lesion.

5. **Diagnosis of Internal Root Resorption**

Internal root resorption (IRR) within the root canal can also be identified by CBCT. IRR is usually asymptomatic, slowly progressing, and presents as an incidental finding on a radiograph. Using conventional PA radiographs, it is common that internal and external inflammatory root resorption maybe misdiagnosed. Because these conditions represent different pathological processes and require different treatment protocols, it is important that they are distinguished clinically sooner rather than later. Diagnosis using conventional PA radiography is difficult and requires multiple angled radiographs. The appearance of internal resorption, unlike external resorption, has clearly defined borders with no canal radiographically visible in the defect. Invasive cervical resorption (ICR) mainly presents with an irregular radiolucency and intact root canal (45). CBCT has been used successfully to confirm the presence of IRR and differentiate it from ICR (24).
6. **Diagnosis of Root Fractures**

CBCT has become useful in the diagnosis of root fractures. Vertical root fractures (VRFs) are frequently difficult to diagnose which can lead to root canal treatment of a hopeless tooth or unnecessary surgery/extraction. The prevalence of VRF has been reported to range from 10.9% (46) to 12.9% (47), with highest incidence occurring in an age group of 40–60 years (48). The teeth most often affected were mandibular molars and maxillary premolars (48). Various factors have been attributed to the cause of these fractures (49,50). Endodontically treated teeth and extensively restored teeth were shown to be predisposed to VRFs (51). Presence of posts in root canals accounted for 61.7% of root fractures (50). Film based intraoral PA radiography has been used for diagnosing root fractures but with poor sensitivity (52). A VRF may be seen directly on a conventional PA radiograph if the x-ray beam is in the same plane as the fracture. However, the lack of consistency of conventional PA radiographs to visualize VRFs may justify the use of alternate imaging modalities to improve their detection (53). Cohenca et al (24) addressed the use of CBCT in the diagnosis of traumatic injuries. Elimination of superimposition of anatomic structures allows the clinician to analyze the fracture clearly. Hassan et al. (54) compared the accuracy of 4 observers in detecting ex vivo VRFs on CBCT and periapical images and assessed the influence of root canal filling on fracture visibility. They found an overall higher accuracy for CBCT (0.86) scans than periapical radiographs (0.66) for detecting VRF. Another study by Bernardes et al. (55) retrospectively compared conventional periapical radiographs and CBCT images for 20 patients with suspected root fractures. They found that CBCT was able to detect fractures in 18 (90%) of patients whereas conventional periapicals could only detect fractures 6 to 8 of the cases (30% to 40%). A recent study by
Edlund et al (56) examined 32 teeth in 29 patients with clinical signs and symptoms suggestive of VRF. Each subject then underwent surgical exploration as a part of treatment, which helped establish the presence or absence of VRF. The sensitivity of CBCT for detection of VRF was 88%, and the specificity was 75%. The overall accuracy was 84%. This study also compared two different CBCT machines (iCAT and Accuitomo), which have different voxel sizes. They demonstrated that in addition to the superior diagnostic performance of CBCT for VRF detection, the sensitivity and specificity of data with smaller voxel sizes were higher. This might indicate that a limited FOV with the smallest isotropic acquisition voxel size might enhance detection of VRFs.

7. **Review of related literature**

There have not been any previous studies regarding the direct comparison of periapical radiographs and CBCT in changing a clinician’s treatment decision process.

The majority of studies demonstrate the technological advantages of CBCT in the diagnosis of endodontic pathology, pre-surgical assessment, analysis of resorption lesions, and assessment of root fractures. When compared to conventional PA radiography, CBCT provides a three-dimensional view of the roots and surrounding structures without superimposition and geometric distortion. The most important advantage of CBCT in endodontics is that it demonstrates anatomic features in 3D that intraoral PA images cannot (57). The superior visualization of the maxillofacial region facilitates accurate diagnosis and influences treatment planning.
III. METHODS

A proposal of the research project “Comparison of Endodontic Treatment Planning with Cone Beam CT and Periapical Radiography” was submitted to the Institutional Review Board (IRM) for exemption, which was granted on September 28, 2011. (Research protocol number (2011-0812).

A. STEP 1: Case Selection

Thirty retrospective patient cases taken from the private practice of an endodontic office in Chicago, IL were chosen randomly from a list of all CBCTs taken at that office. The inclusion criteria required patients to be 18-64 years old who presented to the endodontic private practice for treatment. Pregnant women were excluded. Thirty teeth from twenty-eight different patients were evaluated. Each case included at least one digital PA radiograph taken on a Schick CDR intraoral digital sensor (Schick Technologies, Long Island, NY) and a CBCT image taken with a Kodak 9000 3D (Kodak Carestream Health, Trophy, France). The purpose of the radiograph and CBCT scan were for diagnostic reasons unrelated to this research study. All radiographs had all personal identifiers removed. To prevent confusion from adjacent teeth and structures each radiograph and CBCT image will have the tooth number to be examined labeled. Two patients had two teeth present in the same radiograph and CBCT. The radiographs and CBCT images from these two cases were duplicated and placed in random order of 30 cases to be examined.
Examiners will be told to examine that particular tooth only and to ignore any other pathology seen on the same radiograph or scan. These de-identified radiographs and CBCT scans will be randomized from a master list.

**B. STEP 2: Radiograph Diagnosis**

Three board certified endodontist evaluators were shown the 30 randomized periapical radiographs individually. Evaluators were asked to give a preoperative radiographic diagnosis based on the PA radiograph. The list of choices include:

1. Periapical Radiolucency only
2. Vertical Root Fracture
3. Internal or External Resorption
4. Perforation
5. No radiographic pathology

These choices were chosen carefully to include the most likely and most commonly seen radiographic findings. Furthermore, since the study is retrospective, there was a definitive diagnosis and treatment performed on each of the cases. The definitive clinical diagnosis will be referred to as our “gold standard” because it is the final diagnosis that the clinician came to when the case was treated in private practice. The above list of choices was created based on the definitive diagnosis of all the cases. While it is possible that some cases may include two or more of the above choices, the evaluators were asked to circle which choice is the radiograph
most indicative of. For example, if the radiograph has an obvious resorptive defect as well as a periapical radiolucency, the examiner would be asked to circle resorptive defect.

C. **STEP 3: Radiograph Treatment Plan**

In addition to the radiographic diagnosis, the evaluator then selected from a list their preliminary treatment plan for each case based on their radiographic diagnosis. The list of treatment plan options was again created carefully remembering that these cases were treated in private practice and that all treatments performed outside this study be listed as an option to the examiner. The list includes:

1) Conventional “First Time” Root Canal Treatment
2) Root Canal Retreatment
3) Orthograde Perforation repair with Root Canal Treatment
4) Endodontic Surgery (May include perforation repair, Apicoectomy, Biopsy)
5) Extraction

It should be noted that the option to do nothing is not present in this list. This is because all 30 cases had some sort of treatment performed from the above list. This forces the examiner to choose an endodontic treatment rather than not. If an examiner circled “No radiographic pathology” for their radiographic diagnosis, by default, they should circle “Conventional RCT” from the list of treatment assuming the case did not have a root canal filling. This is justified because no clinical signs or symptoms were included in this study and since some treatment was performed on the patient, it is the only answer that fits. Outside this study it can be assumed that
a case without radiographic pathology may have irreversible pulpitis and was seen for conventional RCT. Just like the radiographic diagnosis list, it is possible that some cases may include two or more of the above choices. The evaluators were asked to circle which choice is the most significantly related to treatment success. For example, if the tooth required a perforation repair as well as root canal retreatment, the examiner would circle perforation repair. Also, if the tooth required a root canal retreatment followed by a surgery, the examiner would circle surgery. At the conclusion of the 30 radiographic case evaluations the randomized order of radiographs and their corresponding results were reorganized into the master list.

D. **STEP 4: CBCT Diagnosis and Treatment Plan**

Two weeks after evaluation of digital radiographs, the 3 evaluators were shown 30 CBCT reconstructions taken on the Kodak 9000 3D belonging to the same patients as had been seen for the periapical radiographs. These 30 scans were randomized differently from the list of radiographs. The images were of the same teeth as the periapical radiographs. Each examiner will be allowed to adjust and move through the volumes freely without a time limit. They were asked to complete the same two lists of radiographic diagnosis and preliminary treatment plan from each of the scans in the same manner as was done for the digital PA radiographs. The randomized list of CBCT scans was then be reorganized into the master list.
E. **STEP 5: Data Analysis and Comparison of Treatment Plans**

The diagnosis and treatment plans from both imaging modalities was then compared to see if there was a deviation from the preliminary radiographic diagnosis and the preliminary CBCT diagnosis. We also compared the imaging diagnosis from these two modalities to the gold standard which is the definitive clinical diagnosis attained from the endodontic practice.

The treatment plans from the radiograph group were compared to the CBCT group to see if there was a significant difference between them. This was an independent intra-examiner comparison. The examiners were not be compared to one another to assess how their results were similar or different on the cases. Rather, each examiner had their own radiographic list compared to their own CBCT list. This method of comparison was used to eliminate the clinician decision discrepancies between examiners. While each examiner is a Diplomate of the American Board of Endodontists, their clinical decision making philosophies may still differ.

Statistical analysis was performed by using Microsoft Excel (Microsoft Corp, Redmond, WA) 2008 software and SPSS Software (IBM, Armonk, NY).

1. **Descriptive Statistics**

The list of radiograph and CBCT diagnoses were compared to the gold standard for each examiner. The amount of cases matching the gold standard were compared for the radiographs and CBCT images.
2. **Chi-Square Test**

The Chi-Square Test was performed to answer the following question:

a) Is there a significant change in treatment plans between the radiographs and CBCT images for each examiner?
IV. RESULTS

A. Collection of data

A total of 30 different endodontic related cases were examined with both digital PA radiographs and CBCT volumes.

B. Comparison between gold standard and radiographs

The radiographic analysis and gold standard were compared. The radiographic analysis was a match with the gold standard in 11 out of 30 cases (36.6%) for examiner 1, 11 out of 30 cases (36.6%) for examiner 2 and 12 out of 30 cases (40%) for examiner 3.
C. **Comparison between gold standard and CBCT scans**

A positive comparison between the CBCT analysis and gold standard was present in 25 out of 30 cases (83.3%) for examiner 1, 25 out of 30 cases (83.3%) for examiner 2 and 23 out of 30 cases (76.6%) for examiner 3.
Figure 2. CBCT to Gold Standard Positive Comparison

D. Comparison between radiographs and CBCT to Gold Standard diagnosis

A higher number of cases from the CBCT group were in agreement with the gold standard when compared to the radiographs and the gold standard. The difference between the two imaging modalities was 14 out of 30 cases (46.6%) for examiner 1, 14 out of 30 cases (46.6%) for examiner 2 and 12 out of 23 cases (52%) for examiner 3.
E. Treatment plan changes between radiographs and CBCT

Each examiner made a preliminary treatment plan based on the radiographic diagnosis and CBCT image diagnosis. Thirty treatment plans based on the radiographs were compared to the 30 treatment plans based on the CBCT images. A change in each examiner’s treatment plan between the two imaging modalities was recorded in 19 out of 30 cases for examiner 1 (63.3%), 17 out of 30 cases for examiner 2 (56.6%), and 20 out of 30 cases for examiner 3 (66.7%).
Figure 4: Treatment plans changed between radiographs and CBCT

F. Chi-Square Test

a. There was a significant change in treatment plans between the radiographs and CBCT images for examiner #1 (P=0.001), examiner #2 (P=0.012) and examiner #3 (P=0.008). We reject the null hypothesis that a preoperative CBCT image does not significantly change an operator’s proposed treatment plan from a preoperative PA radiograph.
V. DISCUSSION

A. Limitations of Study

While dental imaging is most certainly an important factor in diagnosis and treatment planning, it must be acknowledged that imaging should always compliment the clinical examination. This study did not include any clinical tests or patient complaints.

A patient’s chief complaint is usually very helpful in determining which tooth requires treatment. The description of this complaint could also be of value in determining a proper course of treatment for this tooth. For example, if a patient complains of pain on biting and pain on release it may be indicative of a cracked tooth. Swellings in the area will definitely alert the clinician to an abscess. Throbbing in the area may be indicative of symptomatic apical periodontitis. If the main complaint was recorded with our images it could have changed the examiner’s decisions on some of the diagnosis and treatment planning options.

Vitality testing and percussion testing are both important tests that aid a clinician in determining an accurate diagnosis as well as treatment plan. Had vitality testing been recorded in these cases it could have influenced the examiner’s decision as to if there was a periapical radiolucency visible on the radiograph. Percussion testing could have also been useful in determining if previously root canal filled teeth required retreatment or not.
Periodontal pocket measurement is an important clinical exam in the determination of vertical root fractures and external cervical resorption defects. Isolated perio pockets suggestive of a fracture could have influenced the radiographic and CBCT diagnosis as well as the treatment plan for these cases.

Visual exam is also important in diagnosis. Perforations and resorption lesions may be seen clinically but not radiographically. These could have influenced the diagnostic results as well as the treatment planning results.

In addition to clinical tests, the patient’s medical and dental history was also absent in this study. A patient’s medical history is important in treatment planning especially if surgery is required. A more complex medical history could potentially influence a clinician’s decision to perform retreatment or surgery. The dental history is important to know because it tells us how long ago restorations were placed, who performed the previous treatment, what materials or fillings were used, and the frequency and duration of symptoms. If the tooth has had previous root canal treatment, it might have some advantage to know the diagnosis of the tooth before it got a root canal. Also, any complications associated with the first treatment could also provide valuable information.
B. Implications for clinical practice

This study demonstrates that CBCT is more accurate in diagnosing endodontic pathology. While 2-dimensional radiographs were accurate from 36.6% - 40% (37.7% average) when compared to the gold standard, CBCT images were accurate from 76.6% - 83.3% (81.1% average). This illustrates the superior diagnostic quality of the CBCT when compared to the definitive diagnosis acquired clinically. Periapical radiographs demonstrated a much lower correlation than CBCT when compared to the gold standard. This high level of misdiagnosis is clinically relevant especially in cases of external inflammatory root resorption where a lack of identification could lead to tooth loss. CBCT clearly identifies important anatomical structures and aids in surgical treatment planning as well as non-surgical perforation repairs or resorption repairs.

This study also demonstrates how a clinician’s treatment plan is directly influenced by the information gained in the CBCT image. In our study the examiner’s altered their treatment plan between the radiograph and CBCT in 19 out of 30 cases (63.3%), 17 out of 30 cases (56.6%), and 20 out of 30 cases (66.7%). An average of 62.2% of initial treatments based on conventional periapical radiographs were altered when the examiner evaluated the corresponding CBCT image of the same case. This high number indicates that CBCT did have a significant influence on the examiner’s treatment plan.

It can be concluded that a preoperative CBCT image does provide more diagnostic information than a preoperative PA radiograph and that this information directly influences a
A clinician’s initial treatment plan. The importance of such information can be valuable in treating conditions quickly and efficiently. A more confident treatment plan can not only help a clinician in his decision making process but also increase their probability of success.

C. **Future Studies**

Future studies may further evaluate the ability of a preoperative CBCT imaging to change a clinician’s treatment plan. Although imaging is a very important diagnostic tool in endodontics, it should always be used as an adjunct to the clinical exam. The addition of clinical tests with medical and dental histories may provide a better clinical picture which may help an endodontist treatment plan a case more accurately and efficiently. It would be of great interest to find out if there is still a change in treatment plans between radiographs and CBCT images when clinical tests like vitality testing, periodontal probing and percussion testing are recorded.
VI. CONCLUSION

In our study we compared the diagnosis and treatment plan of 30 periapical radiographs to 30 CBCT images of the same case. A change in the examiner’s treatment plan between the two imaging modalities was recorded in 19 out of 30 cases examiner 1 (63.3%), 17 out of 30 cases examiner 2 (56.6%), and 20 out of 30 cases examiner 3 (66.7%).

The significance of this study for the field of endodontics is to not only illustrate the enhanced diagnostic ability of the CBCT but to demonstrate how the additional information can influence a practitioner’s treatment plan and clinician decision making. It may assist the clinician in early identification of pathology and assessing the extent of disease as well as pre-surgical treatment planning.

This study lays the foundation for subsequent research, which will attempt to include clinical tests and dental histories into the radiographs and CBCT imaging cases. This will provide further information as to which imaging modality, if any, is superior to the other in providing an accurate, reliable and definitive treatment plan for the patient.
VII. CITED LITERATURE


### VITA

<table>
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<th>Name:</th>
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<tbody>
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