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# Comparison of Endodontic Treatment Planning Decisions Using Cone Beam Computed Tomography versus Periapical Radiography in Previously Endodontically Treated Molars

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## Abstract

**COMPARISON OF ENDODONTIC TREATMENT PLANNING DECISIONS USING CONE BEAM COMPUTED TOMOGRAPHY VERSUS PERIAPICAL RADIOGRAPHY IN PREVIOUSLY ENDODONTICALLY TREATED MOLARS.**

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DEPT OF ENDODONTICS

Objectives: The aim of this study was to determine if treatment plans differ when evaluating previously endodontically treated molars using periapical images (PA's) alone versus PA's and CBCT.

Methods: A retrospective cohort chart review was conducted including 67 previously treated molars that had a CBCT taken. Two calibrated board-certified endodontists evaluated standard PA's. A data sheet questionnaire regarding radiographic findings and treatment plan decisions was completed. Two weeks later, the same steps were repeated but the examiners evaluated both PA's and CBCT images and again arrived at a recommended treatment plan.

Results: Agreement between raters was assessed with Cohen's Kappa statistic. Change in treatment planning decisions between the PA's alone and the CBCT evaluation was assessed using McNemar's Chi-squared test. There was a significant difference in the proposed treatment planning decisions as they differed in 48% of the cases.

Conclusion: The use of CBCT imaging altered treatment planning 48% of the time in molar retreatment cases supporting the rationale for the use of CBCT as presented in the AAE and AAOMR position paper.

## Introduction

Radiographic examination is an essential diagnostic tool in the field of dentistry. Today, both two-dimensional (2D) and three-dimensional (3D) techniques are available for case assessment and diagnosis and treatment planning.

Over 100 years ago, radiography aided in the transformation of the field of dentistry into an advanced and more sophisticated healthcare profession. Dr. Otto Walkoff was the first one to accommodate the use of radiography to the oral cavity, which was in 1896. It was reported that the first x-ray production was as early as 1785 by William Morgan, but his findings went undocumented until the announcement of the x-ray discovery by Röntgen in 1895. The very first dental radiograph on a living patient was taken by Dr. Edmund Kells in the United States. As the radiology field has grown, more advances have been growing with it. Conventional radiographs with films changed to digital sensors, and the first digital radiography system was launched in 1987. Reduction in radiation exposure and production of more detailed images were some of the major advantages provided by digital radiography. (1)

Cone beam computed tomography (CBCT) has existed since the 1980s. However, its applications have recently become a viable option for the endodontic office. (2) Today, CBCT is considered an extremely strong tool for diagnosis, treatment planning and follow up in the field of endodontics. CBCT enables us to view teeth in three different views, sagittal, axial and coronal, and this is considered a remarkable advantage over traditional two-dimensional (2D) radiographs. CBCT overcomes one of the limitations of 2D imaging modalities which is geometric distortion that affects the interpretation accuracy and ultimately the diagnostic value of the images. (1) Combining a clinical examination with diagnostic testing, including a radiographic examination,

allows the dentist to generate a better understanding of the situation. Each case should be assessed individually to determine whether or not a CBCT scan is indicated. There should be justification of the radiation exposure to the patient, the benefits should outweigh the risks and the additional radiation should be kept as low as reasonably achievable. (3) Clinicians should use CBCT when the need for diagnostic imaging cannot be met by lower dose 2D imaging modalities. It can be used as a complementary method for specific case scenarios, but it does not yet replace traditional 2D imaging modalities. CBCT has been used for pre-operative, intra-operative and post-operative assessments. Despite the advantages of CBCT, there are some limitations and dosage considerations when deciding the imaging modality for each individual case.(4) Scatter and beam hardening have a significant effect on the quality of the CBCT image and therefore will have an impact on the interpretation of the scan. (3)

The advent of 3D imaging has provided the endodontist with tools that were not available to the clinician before. It has facilitated interactive image manipulation and enhancement to visualize the area of interest as a 3D volume. Lack of distortion, magnification, artifacts associated with conventional radiography, and the relative low radiation dose in comparison with medical-grade CT will result in more clinicians adopting such technology to enable accurate diagnoses and treatment planning, in addition to long-term follow-up and evaluation of healing. (5)

A CBCT machine is composed of a rotating frame-work, a fixed x-ray source and a detector. The area of interest will be radiated with a cone-shaped source of ionizing radiation. Both the x-ray detector and x-ray source will rotate around a fixed point and then, many planar projection images will be obtained. An accurate 3D image will then be acquired. (3)

For endodontic applications, a limited field of view is recommended for the area of interest and will include the teeth in question and their surrounding structures, it will reduce the radiation

dose that the patient is exposed to. The radiation dose of a limited field of view (LFOV) is approximately equal to 2-7 periapical radiographs. (2) Resolution provided by the LFOV, which is 5cm x 5cm, allows for assessment of loss of the lamina dura and widening of the periodontal ligament (PDL) necessary for the diagnosis of periapical pathosis. (3)

Often in practice, root canal treated teeth with persistent periapical lesions are referred for evaluation and endodontic re-treatment. Several factors can lead to endodontic failure. These factors include, an in-correct diagnosis, untreated missed canals, perforations, crown fractures, vertical root fractures, coronal leakage and the presence of technical errors such as separated instruments and poor quality of the root canal filling. Diagnosis and correct treatment planning can be generated with careful clinical examination and radiographic evaluation. (6) CBCT stands out among the other imaging modalities in providing an accurate assessment due to the high image quality it is able to generate. (7).

It has been shown that the presence of iatrogenic perforations and root canal filling extrusion significantly affect the long-term survival of the tooth, but the use of CBCT was more accurate in diagnosing the different types of technical errors and associate them with endodontic therapy outcomes. (7) Technical errors and periapical lesions used to be evaluated using periapical radiographs for a long period of time. Recently, new associations between the different kinds of technical errors, the quality of the obturation and the endodontic outcomes have been established and reinforced when evaluation was done using CBCT. (8) Visualizing these types of errors on a CBCT image allows the endodontist to approach the case in a more predictable manner and helps in patient education to understand the situation of the tooth and its prognosis.

According to Cheung's CBCT analysis study, underfilling was one of the most frequent type of technical errors in root canal treated teeth. In maxillary molars, the most common error

found was the absence of root canal filling in the second mesio-buccal canal. (9) Inadequate coronal seal was another factor linked to the periapical status. It was found that a poor quality coronal restoration after a good quality root canal therapy can significantly lower the success rate. (10) Due to the amount of artifact generated by high- density materials, CBCT is not indicated to evaluate the quality of dental restorations. In fact, clinical evaluation of the restoration and radiographic examinations are considered to be superior methods for the purpose of evaluating the final restoration and detecting any open margin present. (9)

It is of a great value to assess the different factors that have an impact on root canal treatment outcomes. According to Liang et. al, who identified outcome predictors with periapical radiographs, periapical radiographs detected periapical lesions in 18 roots (12%) as compared to 37 on CBCT scans (25%). More than 75% of the root fillings that appeared short on the intraoral radiographs were actually flush on CBCT images. This led to the conclusion that treatment outcome, root canal length, obturation density and outcome predictors determined using CBCT showed significantly different values in comparison to intraoral radiographs. (11)

In 2014, Ee's study compared treatment planning decisions using CBCT versus intraoral radiographs. They found that accurate diagnosis was reached in 36%-40% of the cases with intraoral radiographs compared to 76%- 83% with CBCT. This emphasized the significant influence of CBCT in treatment planning an endodontic case.(12)

The AAE and AAOMR Joint Position Statement recommends considering a limited field of view CBCT as the image modality of choice for presurgical treatment planning and implant placement. LFOV CBCT aids in localizing root apices and assessing their proximity to vital surrounding anatomic structures. Compared to intraoral radiographs, CBCT improves the visualization of the size and extent of the periapical lesion and how close they lie to anatomic

landmarks. (13) It was also found that 34% of lesions detected with cone beam tomography were missed when evaluated using periapical radiographs in maxillary premolars and molars. (14) In a study done by Venskutonis et. al, the superiority of CBCT imaging to detect missed canals and bone lesions was confirmed. (15)

One of the most important applications of CBCT imaging for endodontics could be the assessment of periapical healing post root canal therapy, since its geometric accuracy is superior to conventional methods. CBCT has an important role in detecting periapical pathology that was not detected using conventional radiographic methods which many studies have shown. (9,16,17) In Tsai's study, the diagnostic accuracy of two CBCT machines and periapical radiography in detecting simulated apical lesions were compared. They found that both CBCT devices demonstrated fair to good accuracy when simulated lesion diameter was between 0.8–1.4 mm, and excellent accuracy when simulated lesions were larger than 1.4 mm in diameter. (18) According to Paula-Silva, apical periodontitis was detected in 71% of the roots using periapical (PA) radiographs, while CBCT detected apical periodontitis in 84% of the roots, and histological testing revealed apical periodontitis in 93% of the roots. (19) Patel's study showed that the healed and healing rates of molars with root canal therapy decreases when CBCT was used as a diagnostic method compared to PA radiographs. At a one year recall, when CBCT was used for assessment, the failure rate of teeth without periapical pathology was 14 times higher in comparison to PA radiographs. (17) Several clinical studies compared the detection of periapical pathosis with intra-oral radiographs versus CBCT. CBCT was able to identify primary endodontic disease in 48% of the cases compared to 20% using 2D images. CBCT was shown to be superior to intraoral radiography in detecting bone loss. (11) Moreover, this advanced technology can help in determining the exact size and the impact of non-endodontic pathosis on the surrounding tissues.

According to one retrospective analysis, CBCT provided more information compared to PA radiographs in terms of the anatomy of the roots and canals along with the size and location of the periapical lesion. (20) It was found that the larger the periapical pathosis, the more reliable the agreement and lack of clear radiographic definition of small sized periapical radiolucencies may create difficulty in diagnosis. (21)

There are essentially four options for the treatment of a tooth that has post-treatment endodontic disease: do nothing, extraction, nonsurgical retreatment, and surgical treatment. Avoiding treatment may result in the progression of disease and continued destruction of supporting tissues as well as possible acute exacerbation of systemic side effects such as cellulitis and/or lymphadenopathy. (22) CBCT will help us better diagnose previously endodontically treated teeth with persistent peri-apical lesions and decide on intervention or no treatment.

The American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) in their Joint Position Statement, *Use of Cone Beam Computed Tomography in Endodontics 2015 Update*, gave scientifically based guidelines regarding the use of CBCT in endodontic treatment:

Recommendation 7: Limited FOV CBCT should be the imaging modality of choice when evaluating the non-healing of previous endodontic treatment to help determine the need for further treatment, such as non-surgical, surgical or extraction. Recommendation 8: Limited FOV CBCT should be the imaging modality of choice for non-surgical re-treatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.(13)

These two recommendations stress how important accurate treatment planning is for endodontic retreatment. Incorrect endodontic diagnosis and treatment planning places the patient at risk and may result in unnecessary treatment. In a study done by Rodriquez et al on the influence of CBCT in clinical decision making among specialists, they found that preoperative CBCT imaging provides more diagnostic information than a preoperative PA radiograph and that this information can directly influence endodontic retreatment strategies. (23) According to Ee et. al, preoperative CBCT imaging provides additional information when compared with preoperative periapical radiographs, which may lead to treatment plan modifications in approximately 62% of the cases.(12)

The advent of 3D imaging has provided the endodontist with tools that were not available to the clinician before. It facilitated interactive image manipulation and enhancement to visualize the area of interest as a 3D volume. Lack of distortion, magnification, artifacts associated with conventional radiography, and the relative low radiation dose in comparison with medical-grade CT will result in more clinicians adopting such technology to enable accurate diagnoses and treatment planning, in addition to long-term follow-up and evaluation of healing.(5)

Despite all the advantages, CBCT is not recommended to be taken routinely, but rather for selected cases in order to ensure that the risks and benefits support its use. (24) In endodontics, there has been debate on CBCT usage and whether or not its usage should be considered as a standard method for imaging.

The aim of this study was to compare treatment planning decisions made when evaluating previously endodontically treated molars using digital radiography alone versus PA's and CBCT to determine if the treatment plan differs based on the 2 different imaging modalities.

## Materials and methods

This was a retrospective cohort dental chart review study that was approved by the institutional review board (VCU IRB #: HM20014338). A randomly selected sample of molar cases referred to the Graduate Endodontic Practice at VCU School of Dentistry for evaluation for retreatment between January 2011 and March 2019 were used for this study. Only cases that had a pre-operative cone beam computed tomography (CBCT) scan and at least one 2-D periapical radiographic image obtained were eligible to be included in the study. After selecting the cases that met the inclusion criteria, the corresponding 2-D and CBCT images were de-identified. Exclusion criteria included patients younger than 18 or older than 89 years old and patients who were pregnant. Since the CBCT scan was taken prior to conducting the study, the clinical protocol for obtaining a CBCT scan was not altered for the purpose of this study. A total of 67 cases were included in this study.

All CBCT scans were taken with the Carestream 9300 system (Carestream Health; Rochester, HY). All CBCT images were taken using a limited field of view (5 x 5 cm) and a voxel size of 0.090mm. Operating parameters were set at 2-10mA, 60-90 kV, and 12 seconds. CBCT images were analyzed using a Dell Optiplex 990 computer (Dell SA, Geneva, Switzerland). All PA's were taken with digital Dexis ™ sensors and viewed as described.

Patients' charts were reviewed by the primary investigator to gather information on whether or not the teeth to be examined were symptomatic. The charts that met the inclusion criteria were reviewed by two calibrated and blinded board-certified endodontists. The two evaluators, independently, arrived at a recommended treatment plan decision based on the provided 2-dimensional images (PA's) or based on the CBCT scan and PA's combined. Under the same testing conditions, examiners were able to manipulate the CBCT and PA's in order to

decide on a treatment plan. The treatment plan decision was based on the provided images, along with the knowledge of knowing the tooth in question was symptomatic or not.

Periapical (PA) radiographs:

The two examiners were calibrated prior to evaluating the patient records that met the inclusion criteria. The de-identified standard radiographs, along with the chief complaint (symptomatic or asymptomatic) were presented to the two endodontists. Both examiners were given a sufficient amount of time in order to evaluate the provided radiographs of 67 cases carefully and provide a treatment plan recommendation based on their findings and the presence of symptoms or not. After evaluating the radiographs, a REDCap data sheet questionnaire consisting of a few questions regarding their radiographic findings and treatment plan decision was completed.

CBCT and PA's combined

Each of the two endodontists were then presented with half of the CBCT scans and PA's of the cases that they evaluated earlier. This was done after a minimum of 2 weeks of their first evaluation. Again, the de-identified standard radiographs, along with the patient's chief complaint (symptomatic or asymptomatic) were presented to the two endodontists along with the CBCT scans to be manipulated using the manufacturer software. Both examiners were given a sufficient amount of time in order to evaluate the provided CBCT scans and PA's carefully and provide a treatment plan recommendation based on their finding. After evaluating the scans and radiographs, the same REDCap data sheet questionnaire consisting of a few questions regarding their radiographic findings and treatment plan recommendation was completed.

The purpose of the questions presented in the REDCap survey/data sheet was to evaluate if CBCT imaging added diagnostic value and if it resulted in changes in the treatment plan recommendation. Each question had multiple statements. The examiner could select one or multiple statements that best summarized their findings and their treatment plan recommendation.

The study was conducted in three phases. The first phase, which was the pilot study, consisted of 5 different PA's and their corresponding CBCTs. The aim of the pilot study was to evaluate the feasibility, randomization and assessment procedures in order to identify if any modifications would be needed in the design of the larger study. Calibration of the two examiners was completed after the pilot study. Shortly after, the examiners were presented with a total of 67 cases with their PA's and the information about the tooth being symptomatic or not. Two weeks later, each of the examiners were presented with a total of 33 to 34 cases with their CBCT scans and PA's excluding the 5 cases that were evaluated in the pilot study. They were asked about their treatment recommendation in each of the different phases.

Statistical Analysis:

The radiographic treatment plan and radiographic + CBCT treatment plan was then compared using descriptive statistics (counts and percentages) and McNemar's chi-square test to determine consistency where applicable. Additionally, inter-rater reliability was assessed using Kappa Statistic. All data analysis was performed in SAS EG 6.1 with a significance level of 0.05.

## Results

Etiology and treatment plans were summarized using descriptive statistics (counts, percentages). Agreement between PA's alone versus PA's and CBCT's pre-operatively were assessed using chi-squared tests for symmetry. Cohen's Kappa was calculated to determine the agreement between treatment plans with PA's alone versus PA's and CBCT scans. Agreement between the two scales was assessed using descriptive statistics and Cohen's Kappa. Kappa values between 0.2 and 0.4 are considered "fair," between 0.41 and 0.60 are "moderate," 0.61-0.80 is "substantial," and greater than 0.81 is "almost perfect." Significance level was set at 0.05.(25)

For a total of 67 cases reviewed, each rater had reviewed all 67 cases with PA's alone first and then each rater reviewed 33 or 34 PA's and CBCT later. The pre-operative findings were dependent on the type of image being viewed (Table 1). The majority of the cases had a radiolucency or an area of low density when they were viewed using PA's alone (54 cases (81%), versus PA's and CBCT's (61 cases (91%) respectively), p-value (<0.02). Other common findings were inadequate obturation length, which was found in 25 (37%) of the cases that were reviewed with PA's and 23 (34%) of the cases when CBCT was reviewed, p-value (0.5). Regarding obturation density, 17 cases (25%) were considered to have non-dense fills when evaluated using PA's only, whereas 27 cases (40%) of them were considered to have non-dense fills when evaluated using CBCT, p-value (0.01). CBCT did not add any benefits in detecting the presence of a separated instrument, 6 of the cases (9%) were identified in this category when evaluated by either PA's alone or with CBCT combined. Seven cases (10%) had bone loss consistent with vertical root fracture when the PA's were viewed, but when reviewing the CBCT, the number of cases increased to a total of 12 cases (18%) with a p-value equal to 0.05. A

perforation was noted in 2 and 5 of the cases when PA's and CBCT were reviewed respectively, however the difference was not statistically significant. There was a statistically significant difference (p-value <0.05) for detecting missed treated canals when evaluating PA's vs CBCT (9%, 24% respectively). Six cases (9%) had normal radiographic findings when PA's were reviewed, and none of them had normal findings when evaluated using CBCT (p-value <0.0001). None of the cases were identified to have internal or external root resorption in either PA's or CBCT's. Results are displayed in Table 1.

| **Pre-operative Findings (N=67)** | **PA** | **CBCT** | **p-value** |
|---|---|---|---|
| Periapical radiolucency (PA), area of low density (CBCT) and/or PDL widening | 54, 81% | 61, 91% | 0.0196 |
| Bone loss consistent w/vertical root fracture | 7, 10% | 12, 18% | 0.0588 |
| Perforation | 2, 3% | 5, 7% | 0.1797 |
| Missed canal (s) | 6, 9% | 16, 24% | 0.0016 |
| Inadequate obturation length | 25, 37% | 23, 34% | 0.5637 |
| Inadequate obturation density | 17, 25% | 27, 40% | 0.0124 |
| Separated instrument | 6, 9% | 6, 9% | 1.0000 |
| Normal radiographic findings | 6, 9% | 0, 0% | <0.0001 |
| Other | 0, 0% | 16, 24% | <0.0001 |

Table 1: Pre-operative Findings based on Image Method

From the 33 cases that rater 1 evaluated, 16 cases had the same Tx plan when PA's were evaluated alone or in conjunction with CBCT. However, the Tx plan had changed in the remaining 17 cases. The percentage of Tx plan changes for rater 1 when reviewing PA's and CBCT compared to PA's alone was found to be 52%. From the 34 cases that rater 2 evaluated, 19 cases had the same Tx plan when PA's were evaluated alone or in conjunction with CBCT. The treatment plan did change in the remaining 15 cases. The percentage of Tx plan changes for rater 2 when reviewing PA's and CBCT compared to PA's alone was found to be 44%. Overall, from the total of 67 cases, the raters had different treatment plans in 48% of the cases when reviewing PA's and CBCT compared to PA's alone. In 52% of the cases, the treatment plan was the same regardless of the type of imaging modality that was reviewed.

The agreement between the treatment plan on the PA's and the PA's with CBCT combined was fair (kappa=0.24; 95% CI: 0.10-0.39). After categorizing the treatment plan into NS retreatment or Other (no treatment, surgical, orthograde perforation repair, extraction, root amputation, intentional replantation, or other), the agreement increased but was still weak (kappa=0.34; 95% CI: 0.12-0.56). Results are displayed in Table 2.

From the total of 67 cases, the agreement between the NS retreatment based on PA's alone and when combined with CBCT was noted in 28 of the cases. The agreement on surgical Tx (including perforation repair, apical surgery and/or biopsy) based on PA's alone and combined with CBCT was noted in 4 of the cases only. Only 2 of the cases planned for extraction and 1 of the cases planned for no treatment based on PA's alone were planned for the same treatment option when PA's and CBCT were reviewed together. When the evaluation was done using PA's only, the examiners selected the extraction option in 4 out of the total 67 cases

(5.9%). After viewing the CBCT scan, the extraction option rose to 11 cases (16.4%) out of the total number. The increase was statistically significant.

A total of 32 cases had a different Tx plan when evaluated using PA's and CBCT versus PA's alone. According to the analysis, the most commonly noted Tx plan change when evaluating PA's and CBCT compared to PA's alone was from NS retreatment to surgical Tx, which was found in 7 out of the 32 cases. Six of the cases were planned for NS retreatment when both PA's and CBCT were reviewed. In four of these cases, the raters elected no Tx based on PA's alone. Results are displayed in Table 2.

Table 2: Comparison of Treatment Plan with PA's only and PA's and CBCT combined

| | | PA's and CBCT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **No Tx/ observe** | **NSReTx** | **Surgical Tx (includes. Perf repair, apical surgery and/or biopsy)** | **Orthograde Perforation repair** | **Extraction** | **Root amputation** | **Intentional Replantation** | **Other** | |
| **PA's only** | **No Tx/ observe** | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 1 | **8** |
| | **NSReTx** | 1 | 28 | 7 | 0 | 5 | 0 | 0 | 3 | **44** |
| | **Surgical Tx (includes. Perf repair, apical surgery and/or biopsy)** | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | **6** |
| | **Orthograde Perforation repair** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| | **Extraction** | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | **4** |
| | **Root amputation** | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | **2** |
| | **Intentional Replantation** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **1** |
| | **Other** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| | | **4** | **34** | **13** | **0** | **11** | **0** | **0** | **5** | **N=67** |

## Discussion

The desired goal of this study was to determine if CBCT interpretation added important information that might alter treatment planning decisions. In previously treated molars, CBCT helped in better assessment of the pathology. Furthermore, CBCT aids in accurately understanding the etiology of endodontic failures to reach a more accurate treatment plan.

Regarding pre-operative findings, it was found that they were dependent on the type of image being viewed. Many pre-operative findings changed significantly when viewed on the CBCT compared to PA's, except for inadequate obturation lengths. CBCT detected more cases with periapical changes, bone loss consistent with vertical root fracture, perforations, untreated canals, all of which were consistent with previous studies. (17)(3)(26) In this study PA's detected a periapical radiolucency in 81% of the cases, CBCT scans detected a periapical radiolucency in 91% of the cases. None of the cases had normal radiographic findings when CBCT scans were evaluated, whereas 9% of them had normal radiographic findings based on the PA's alone. A previous study evaluated the accuracy of two imaging methods (PA's and CBCT's) in diagnosing apical periodontitis (AP) using histopathological findings as a gold standard and they found similar results. PA's detected AP in 71% of roots, CBCT scans detected AP in 84% of the roots and histopathological findings detected AP in 93% of the roots. The accuracy of CBCT scans in diagnosing AP was 92%. They concluded that CBCT diagnosed a healthy periapex more accurately than PA's. (19) Another study found similar results as well and indicated that CBCT had significantly higher diagnostic accuracy in detecting AP compared to periapical radiography, using human histopathological findings as a reference standard. (27)

Both raters in this study were board certified endodontists. Rater 1 had 3 years of experience in endodontics and CBCT, whereas rater 2 had 23 years of experience in endodontics in private practice and has been working with CBCT for 6 years in an academic setting. The 2 raters evaluated PA's and CBCT images combined and arrived at a recommended treatment plan. The treatment plan was compared to the one they arrived at when evaluating PA's only.

Each rater evaluated a different set of cases when looking at the CBCT scans, so it was not possible to compare the inter-rater reliability with regard to pre-operative findings and treatment plan decisions. A previous study was done to determine the effect of experience level on the detection of periapical lesions in CBCT volumes. They found that clinicians' experience level appears to be correlated with their ability to correctly diagnose periapical disease in CBCT volumes. In addition, experience leads to better inter- rater reliability. (28)

In this study, the raters altered their treatment plan for 48% of the cases overall when they were evaluated using both PA's and CBCT compared to PA's alone (range 44%-52%). The percentage was similar but slightly lower to that of a previous study. Ee et. al found that alteration in the treatment plan after viewing CBCT scan was 62.2% of the cases overall. (12) Another study was done on the influence of CBCT in clinical decision making among specialists. Their findings suggested that more diagnostic information can be obtained from a preoperative CBCT image than from a preoperative PA radiograph. They concluded that CBCT imaging influenced a clinician's treatment plan, particularly in high difficulty cases. (29)

This study found that the alteration in the treatment plan using the two imaging modalities occurred less with the more experienced endodontist (rater 2) compared to the less experienced endodontist (rater 1). Rater 2 changed his treatment plan based on CBCT and PA combined in 44% of the cases, the remaining 56% had the same treatment plan when evaluated

using PA's only or both imaging modalities. However, rater 1 changed his treatment plan in 52% of the cases based on CBCT and PA's combined. The remaining 48% had the same treatment plan. This suggests that clinicians' experience plays a role in interpretation of CBCT scans. According to Parker et al., more can be done to improve the limited field of view CBCT interpretation skills of clinicians at various levels of experience. (28) Another study done by Barnett et. al concluded that further training is necessary to avoid misinterpreting CBCT volumes and prevent incorrectly diagnosing apical periodontitis. (21)

It was noted that the majority of treatment plan modifications went from a conservative approach when PA's alone were evaluated to a more invasive approach when CBCT was added as an additional diagnostic tool. It was not surprising since CBCT was proven to accurately detect bone changes. CBCT interpretation resulted in more extractions being recommended. When the evaluation was done using PA's only, the examiners selected the extraction option in 5.9% of the cases. After viewing the CBCT scans, the extraction option rose to 16.4%. The increase was statistically significant. The explanation may be because CBCT imaging has greater potential to assess for subtle radiographic signs of apical periodontitis, vertical root fractures, resorptions, perforations, along with the true size and location of the radiographic lesion compared with 2D radiographs. These findings were similar to that of the previous study done by Rodriguez et. al. where the extraction recommendation increased from 9.6% to 15.1% when CBCT was evaluated. (29) A previous study done by Kruse aimed to evaluate how additional information from CBCT influenced the periapical assessment and treatment planning based on clinical examination and periapical radiographs in cases followed up 5-11years after surgical endodontic retreatment. They found that the treatment plans changed for 18 teeth (24.3%). For 14 teeth (18.9%), the change was from no treatment or further observation to a more invasive

treatment plan (surgical retreatment or extraction). Their conclusion was that the use of CBCT for long-term follow-up led to more cases being diagnosed with persisting or recurrent apical periodontitis and hence often led to the recommendation of a more invasive treatment modality. (30)

A recent study looked at the prevalence and size of periapical radiolucencies using CBCT in teeth without apparent intraoral radiographic lesions on PA's. They found that 20% of teeth with successful root canal treatment based on conventional periapical imaging had CBCT radiolucencies measuring greater than 1 mm. Since the histological diagnosis of periapical radiolucencies can't be determined, perhaps no treatment is required in asymptomatic teeth with radiolucencies seen on the CBCT. According to their findings, they did not advocate the use of CBCT imaging as part of follow-up evaluation of previously endodontically treated teeth. (31)

One of the important limitations to this study was the fair agreement for the two raters before the calibration. More accurate results and better reliability would be achieved if the calibration was repeated after completing the second phase of the study, when both evaluators looked at all the PA's and decided on a treatment plan. By doing that, better agreement would be insured before splitting the CBCT scans among the two evaluators. Also, this study can be improved by increasing the sample size and comparing the treatment plan decisions the two evaluators made based on PA's and CBCT scans to the actual treatment performed in the clinic.

## Conclusion

The results of this study suggest that previously endodontically treated molars with symptoms or periapical lesions will benefit from CBCT scans when being evaluated for treatment. Even for more experienced endodontists, CBCT can be invaluable in the assessment and treatment planning of retreatment cases. Based on the results, the information that CBCT adds will definitely benefit the clinician's view and potentially modify treatment planning decisions in endodontic cases, but not all. This study' findings support the rationale for the use of CBCT as presented in the AAE and AAOMR Position Paper.

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# Appendices

REDCap data sheet questionnaire

**Please complete the survey below.**

Thank you!

**Evaluator**

- ○ Dr Jain
- ○ Dr Myers

**Case Code:**

**Images Being Evaluated:**

- ○ PA only
- ○ PA and CBCT

**Select pre-operative findings: (you can select more than one)**

- ☐ Periapical radiolucency (PA), area of low density (CBCT) and/or PDL widening
- ☐ Bone loss consistent w/vertical root fracture
- ☐ Internal or external resorption
- ☐ Perforation
- ☐ Missed canal (s)
- ☐ Inadequate obturation length
- ☐ Inadequate obturation density
- ☐ Separated instrument
- ☐ Normal radiographic findings
- ☐ Other

Select all that apply

**What is your recommended treatment plan?**

- ○ No Tx/ observe
- ○ NSReTx
- ○ Surgical Tx (includes. Perf repair, apical surgery and/or biopsy)
- ○ Orthograde Perforation repair
- ○ Extraction
- ○ Root amputation
- ○ Intentional Replantation
- ○ Other