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The recommendation of Cone Beam Computed Tomography and its effect on endodontic diagnosis and treatment planning

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THESIS

THE RECOMMENDATION OF CONE BEAM COMPUTED TOMOGRAPHY AND ITS EFFECT ON ENDODONTIC DIAGNOSIS AND TREATMENT PLANNING

by

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DEDICATION

I would like to dedicate this Masters dissertation to my wife, Shaima and to my daughters Hannah and Jenna. I have no doubt that without their constant support and motivation, I would definitely not be able to finish this. I would also like to dedicate this thesis to my parents, Maida and Sabri Zuaitar.

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ABSTRACT

Purpose: Although Intra-oral radiographs are foundational for diagnosis and planning treatment in dentistry, the resulting 2-dimensional image varies in interpretation requiring judgement. Cone Beam Computed Tomography provides a more detailed 3-dimensional image that may affect treatment recommendations. This study aimed to determine the basis for CBCT recommendations and its effect on diagnosis and treatment planning. **Methods**: The study involved a sample of 45 cases that presented for endodontic treatment, 30 with a CBCT scan on record and 15 without. For phase I, all 45 cases were reviewed by 3 examiners without access to the CBCT scans. Four months later for phase II, the 3 examiners re-analyzed the 30 cases, this time with the associated CBCT. Intra and inter-examiner agreements were recorded and analyzed. Also, the recommendations for CBCT were compared to the AAE/AAOMR Joint Statement. **Results**: Inter-examiners agreement in phases I and II were 65% and 72% respectively. For endodontic diagnoses, there was 19% change in the pulpal diagnosis category when CBCT was added, while there was 30% change in the apical category. The selections changed in 55% of the cases when determining etiology, and in 49% of the cases when

making recommendations. CBCT was recommended 78.8% of the time when the case had a CBCT on record vs. 33% of the time in cases without. **Conclusion**: CBCT has a significant effect in determining endodontic pathology's etiology and recommending treatment. Further, CBCT is not over prescribed in the endodontic department and the faculty adhere largely to the joint AAE/AAOMR recommendations.

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INTRODUCTION

An accurate diagnosis that leads to an accurate treatment plan is crucial for successful endodontic therapy, and relies on clinical, as well as radiographic data. Since 1895 (1), radiographic images have become an increasingly important adjunct to help diagnose pathologies and plan appropriate treatments. However, conventional radiography provides only a 2D image of a 3D object and superimposition also can result in reduced diagnostic efficacy. In their study, Bender and Seltzer found that periapical lesions do not show in a periapical radiograph until they reach the cortical bone adjacent to the tooth involved (2).

CBCT was introduced to dentistry in the United States after FDA approval in 2001. It uses x-rays that are projected onto the field of interest and then onto a detector while rotating around that area. During this process, hundreds of images are acquired and reconstructed digitally, and thus provide an immediate 3-D radiographic image (3). Accordingly, its use is increasing rapidly in endodontics. Several studies have been conducted to evaluate CBCT's efficacy in identifying endodontic pathologies and to compare this technology to conventional radiographic methods. A study designed to compare diagnostic accuracy in detecting a periapical lesion created artificially using CBCT versus digital periapical radiography (PAR) found that CBCT detected simulated lesions of different sizes and locations more accurately. The study also found that CBCT and PAR did not differ significantly when teeth without periapical radiolucency were evaluated (4).

However, CBCT has disadvantages: it exposes the patient to higher levels of radiation compared to intra-oral radiography; scatter and beam hardening that occur when there is a high-density structure in the area of interest can reduce the image quality, and it also is more expensive (5).

Nonetheless, CBCT has been found to affect decision-making in therapeutic endodontics significantly when used in accordance with the current European Commission guidelines (6). The American Association of Endodontics (AAE) released a joint statement with the American Academy of Oral and Maxillofacial Radiology (AAOMR) with respect to CBCT and recommended its use in endodontics in many situations (7). The statement is an evidence-based list of guidelines with respect to the best uses of CBCT that is based on an extensive literature review. For example, the statement recommends using CBCT to identify the potential presence of a vertical root fracture (VRF). Forty teeth with clinical signs of VRF treated endodontically were evaluated in a study and no fracture lines were detected in PAR, so CBCT scans were used, and the results showed that CBCT was 88% accurate in detecting VRFs (8). However, in a study aimed to investigate the extent of cracks in teeth using PAR and CBCT in vitro, neither CBCT nor PAR was found effective in quantifying the extent of cracks in teeth (9).

Yi et al. carried out a systematic review to compare CBCT and PAR's diagnostic accuracy in detecting external root resorption (ERR). The results indicated that CBCT

was significantly more sensitive than was a PAR, which makes it a reliable method to detect ERR's presence (10).

A study by Schloss et al. demonstrated that CBCT evaluated periapical lesions and healing after endodontic microsurgery more precisely than did PARs (11). However, Kruse et al. showed that 42% of the lesions CBCT detected had no periapical inflammation, but merely scar tissue, as histological studies of the lesions acquired during re-surgery confirmed (12).

CBCT also has been recommended to identify missed anatomy or study a case of unique morphology before or mid-endodontic treatment (7). A study conducted to determine whether CBCT scans can help locate MB2 canals in maxillary molars found that CBCT scans alone have limited ability to do so and were helpful only when used in conjunction with an operating microscope and selective trouphing (13). Another study also indicated that CBCT was no more able to identify complex root canal morphology in premolars than was the gold standard (PAR) (14).

It is challenging for clinicians to identify certain radicular changes, such as perforations, root resorption and VRFs, CBCT has been recommended to increase accuracy in diagnosing such problems (7). Based on Takeshita et al.'s study, CBCT was recommended for identification of ERR and VRFs due to its superior performance, while PAR was recommended for diagnosis of root perforations due to that PAR emits less radiation and achieves similar performance as CBCT (15).

There appears to be some conflict regarding CBCT's efficacy in different aspects of endodontics. Therefore, based on the literature review above, this study investigated

whether a preoperative CBCT changes treatment decisions significantly from a preoperative PAR. This study's goals were to determine whether or not CBCT can provide additional useful information, and whether that information can be used to improve treatment planning when the CBCT is taken in accordance with the guidelines in the AAE/AAOMR's joint position statement. This study also was designed to achieve a better understanding of whether or not endodontic faculty adhere to the AAE recommendations when CBCT is used.

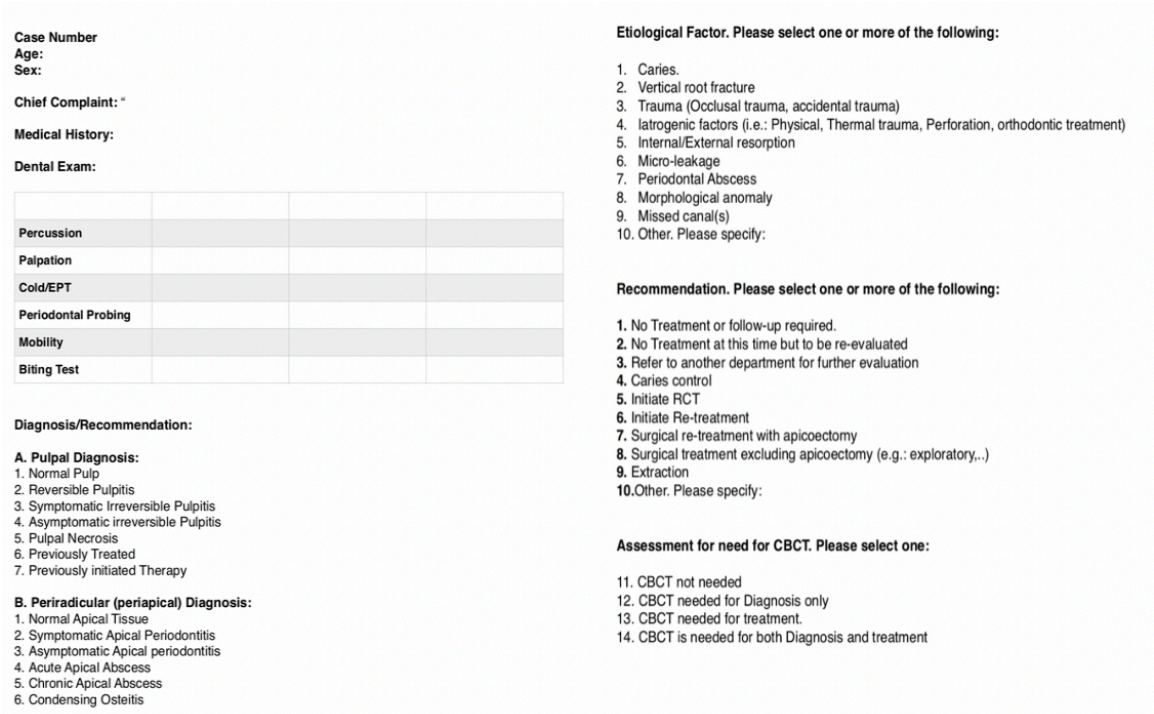
MATERIALS & METHODS

De-identified electronic dental health records (EHR) with CBCT scans were selected for this retrospective cohort study, and at least one faculty member in the endodontic department verified the appropriateness of, and reason that, all CBCT scans prescribed. An application for exemption was submitted and approved by the IRB office before the study began. A code search query was performed using the EHR software to identify records that included a CBCT scan during the period between January 1, 2015 and December 31, 2016 and identified 278 cases. A second query was run on those records, which identified 59 cases that had concurrent CBCT scans and endodontic treatment, including consultation, RCT, NsRetx, and SRCT. One resident reviewed all 59 records to identify cases that included CBCT scans related to the endodontic consultation and/or treatment. Cases were selected regardless of the patient's age, gender, or medical condition and were categorized according to the reason the CBCT was taken based on the recommendations in the AAE/AAOMR joint statement regarding CBCT recommendation. After reviewing all of the cases with CBCT scans, 27 were selected for the study. The remainder were excluded after further review determined that the scan was unrelated to the treatment in question.

Three faculty members were asked to answer all questions for each case. The case and teeth numbers were combined to make one identifier for each tooth, as 4 cases involved 2 teeth, and each was considered a separate case, such that the final number of cases with CBCT was 30. An additional 15 cases were added to the study from the original pool of 278 patients. These did not have a CBCT scan on record that was related

to the endodontic treatment in question; however, they were added to prevent biased decisions when determining whether a CBCT scan was needed. A case template was formatted similar to that of the American Board of Endodontics, which can be found on the Board's website (16). The template included the patient's gender and age, medical and dental history (history of present illness), clinical examination, including endodontic tests and radiographs, and clinical images if available.

In the first phase of the study, unaware of the availability of CBCT, the reviewers were asked to evaluate each of the 45 cases and answer multiple-choice questions related to them. All possible responses were coded as shown in Figure 1.



Case Number
Age:
Sex:

Chief Complaint: "

Medical History:

Dental Exam:

Percussion			
Palpation			
Cold/EPT			
Periodontal Probing			
Mobility			
Biting Test			

Diagnosis/Recommendation:

A. Pulpal Diagnosis:
1. Normal Pulp
2. Reversible Pulpitis
3. Symptomatic Irreversible Pulpitis
4. Asymptomatic irreversible Pulpitis
5. Pulpal Necrosis
6. Previously Treated
7. Previously initiated Therapy

B. Periradicular (periapical) Diagnosis:
1. Normal Apical Tissue
2. Symptomatic Apical Periodontitis
3. Asymptomatic Apical periodontitis
4. Acute Apical Abscess
5. Chronic Apical Abscess
6. Condensing Osteitis

Etiological Factor. Please select one or more of the following:

1. Caries.
2. Vertical root fracture
3. Trauma (Occlusal trauma, accidental trauma)
4. Iatrogenic factors (i.e.: Physical, Thermal trauma, Perforation, orthodontic treatment)
5. Internal/External resorption
6. Micro-leakage
7. Periodontal Abscess
8. Morphological anomaly
9. Missed canal(s)
10. Other. Please specify:

Recommendation. Please select one or more of the following:

1. No Treatment or follow-up required.
2. No Treatment at this time but to be re-evaluated
3. Refer to another department for further evaluation
4. Caries control
5. Initiate RCT
6. Initiate Re-treatment
7. Surgical re-treatment with apicoectomy
8. Surgical treatment excluding apicoectomy (e.g.: exploratory,..)
9. Extraction
10. Other. Please specify:

Assessment for need for CBCT. Please select one:

11. CBCT not needed
12. CBCT needed for Diagnosis only
13. CBCT needed for treatment.
14. CBCT is needed for both Diagnosis and treatment

Figure 1. Image of the template illustrating the way the cases were presented to the faculty reviewers in Phase I and II.

In Phase II of the study, the 30 cases from Phase I were presented to all reviewers 4 months later together with their respective CBCT scans. All CBCTs were reviewed using either Sedexis or I-Cat Vision in a controlled viewing environment. The reviewers answered the same questions as in Phase I with the exception of the "Need for CBCT" section.

Analysis

To assess the need for CBCT, the answers were compiled for all cases and reviewers to measure the frequency with which CBCT was prescribed. Whether it was for or against, each answer was compared to the actual implementation of CBCT in the case. In addition, each case was categorized based on the AAE/AAOMR position statement to determine whether or not the scans followed its recommendations.

The Cohen's Kappa coefficient was used to assess agreement in ratings between Phases I and II for each faculty reviewer. An overall agreement rate also was measured for all of the questionnaire categories.

Only the 30 cases with CBCT were included when CBCT's influence was evaluated. Each faculty member's answers were compared and the data were analyzed using SAS software. The first analysis compared each reviewer's individual answers to each question between Phases I and II to measure the degree to which they changed. Another analysis was performed to measure the differences in the changes in answers between reviewers for each category separately.

RESULTS

In the CBCT's influence section, the results showed a change of only 18.9% in all faculty's pulpal diagnosis (DIAG_A), with slight differences among reviewers. In the periapical diagnosis (DIAG_B) section, the change increased to 30%, with slight differences among reviewers. In the etiological factor (ETIOL) category, the difference increased drastically to 54.4%, with slightly more pronounced differences among faculty reviewers. Lastly, in the recommendation (RECOMM) category, the change was 48.9%, and one reviewer changed significantly more than the others. Table 1 shows the percentages of the answers that remained unchanged in the first and second reviews and the percentages of individual faculty answers that remained unchanged after the cases were presented with CBCT.

Category	REVIEWER-1 (N=30)	REVIEWER-2 (N=30)	REVIEWER-3 (N=30)	*P* VALUE FOR DIFFERENCES BETWEEN REVIEWERS	TOTAL (N=90)
DIAG_A SAME	86.7%	73.3%	83.3%	0.3895	81.1%
DIAG_B SAME	73.3%	76.7%	60%	0.3293	70%
ETIOL SAME	53.3%	36.7%	46.7%	0.4269	45.6%
RECOMM SAME	43.3%	43.3%	66.7%	0.1132	51.1%

Table 1. Percentages of the answers for each category that remained unchanged after the cases were presented with CBCT. DIAG-A: Pulpal diagnosis, DIAG-B: Periapical diagnosis, ETIOL: Etiological factors, RECOMM: Recommendation with percentages per individual faculty member of the answers that remained the same after the cases were presented with CBCT.

When the degree of agreement was measured, it was found that the faculty tended to agree more when CBCT was used. However, although it was clinically relevant, the difference was not statistically significant ($p > 0.05$). The Kappa test results were as follows: for Dx A, agreement improved from 0.68 to 0.70; for Dx B, from 0.62 to 0.73;

for ETIOL_FAC, from 0.42 to 0.44, and for RECOMM, from 0.36 to 0.39. The agreement improved notably overall when CBCT was added to the diagnostic tools offered to the reviewers.

To evaluate CBCT's need in endodontics, the reviewers' responses were compared to its actual implementation. The data for this evaluation is summarized in Table 2.

	CBCT not needed			CBCT needed for Dx Only			CBCT needed for Tx only			CBCT needed for both Tx and Dx		
DMD	Responses	CBCT on record	NO CBCT on record	Responses	CBCT on Record	NO CBCT on record	Responses	CBCT on record	NO CBCT on record	Responses	CBCT on record	NO CBCT on record
DMD-1	20	8	12	23	20	3	0	0	0	2	1	1
DMD-2	19	11	8	11	6	5	7	3	4	8	8	0
DMD-3	14	8	6	1	0	1	23	16	7	7	4	3

Table 2. Reviewers' responses for all cases versus CBCT's actual implementation.

A comparison of the results of the assessment for all cases combined showed that, in 62.2% (n=28) of all of the cases, at least 2 reviewers agreed that CBCT was needed, regardless of the purpose.

In all cases but 5 that had CBCT on record (*n*=30), 2 or more faculty agreed that CBCT was recommended, regardless of the purpose, and in all cases but 3 that had no CBCT (*n*=15), 2 or more faculty agreed that CBCT was not recommended. In general, CBCT was not recommended 16.67% of the time when the case had a CBCT on record. In cases with no CBCT on record, CBCT was not recommended 80% of the time.

When the recommendations for the need for CBCT were compared with respect to whether the case fell under the AAE recommendations (AAE-R), all cases with a CBCT but one did so (*n*=29, 96.6%). Cases with no CBCT that fell within the AAE-R (*n*=9) constituted 60% of the cases with no CBCT (*n*=15), while 40% (*n*=6) of the cases

without CBCT did not fall within the AAE-R. Table 3 shows a detailed analysis of the types of cases based on AAE-R.

AAE-AAOMR CBCT Guideline	Number of cases	CBCT on record	No CBCT on record
Diagnosis of contradictory signs and symptoms	8	6	2
Complex morphology/Dental anomaly	1	1	0
Intra-appointment identification and localization of calcified canals	4	3	1
Detection of vertical root fracture	3	2	1
Localization of lesion/Size of lesion/Non healing lesion	8	6	2
Non surgical retreatment	8	2	6
Pre-surgical treatment planning	5	5	0
Trauma	1	1	0
Internal/External root resorption	4	3	1
Cases not falling under any category	3	1	2
Total	45	30	15

Table 3. Detailed breakdown of the case categories according to AAE-R and the number of cases within those categories.

DISCUSSION

As aforementioned, this study's goal was to measure CBCT's effect on diagnosis and treatment decisions in endodontic cases. The results indicated that CBCT's use affected reviewers' choice when making pulpal and periapical diagnoses, determining etiological factors, and recommending a treatment. The most notable change when the cases with CBCT were presented was determining the etiological factors and the final treatment recommendation. This indicated that CBCT has a great influence on making treatment recommendations based on determination of the etiological factors. These findings are consistent with those of Rodriguez et al., who concluded that CBCT had a direct influence on the treatment decisions dentists make, particularly general practitioners (17).

As CBCT was the only change between Phases I and II, we can conclude that it was the sole factor that affected the reviewers' decisions in Phase II. The results of the Kappa tests confirmed this further, as they showed that the reviewers agreed significantly in all categories. However, the agreement between the reviewers did improve when CBCT was used, and in some cases, very significant improvement was noted. For example, the agreement on the asymptomatic apical periodontitis diagnosis improved significantly with the use of CBCT. This finding confirmed that CBCT improves the detection of asymptomatic apical lesions that conventional 2D radiographs do not detect. Campello et al.'s study designed to determine CBCT's efficacy in detecting PA lesions created artificially concluded that CBCT is more accurate in detecting such lesions, regardless of their size (4).

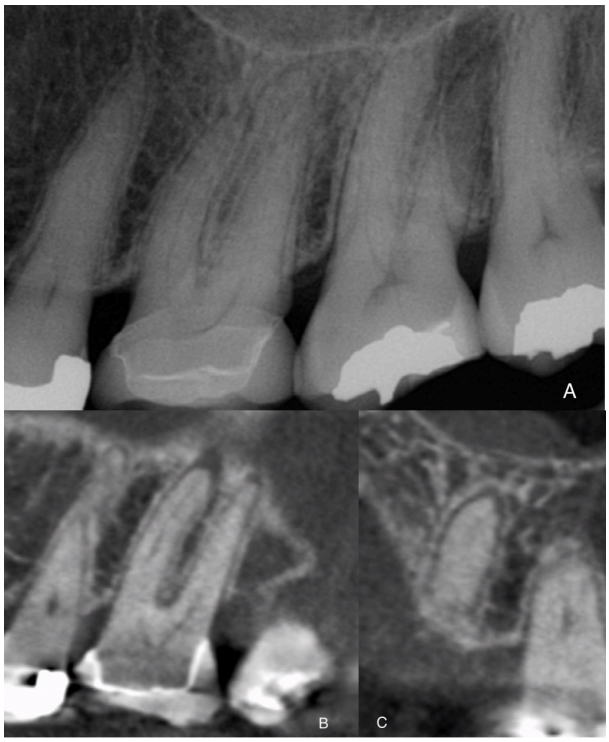


Figure 2. A: PAR of the maxillary left quadrant. First molar showing no peri-apical changes. B: Sagittal section showing both buccal roots with PARL. C: Sagittal section showing palatal root with periodontal space widening

Further, the Kappa test showed that the agreement in detecting a vertical root fracture (VRF) as an etiological factor improved significantly when CBCT was used, which leads to the conclusion that CBCT helps detect VRFs, possibly because of its ability to visualize bone loss patterns that are associated with VRFs in a 3D imaging model, which Saberi et al.'s study that showed that CBCT was 88% accurate in detecting VRFs confirmed (8). Furthermore, the inter-reviewer agreement improved significantly for the missed canals selection in determining the etiological factor for the disease process. Thus, many studies have proven CBCT's ability to detect missed or calcified canals and complex morphology (13, 18).

With respect to the selections in the need for CBCT section, the fact that in approximately 65% of the cases, two or more reviewers agreed whether or not a CBCT should be taken indicated a high level of agreement. This agreement was attributed to the fact that the reviewers adhered strictly to the AAE/AAOMR recommendations, particularly when the recommendation was to obtain a CBCT scan. CBCT was recommended largely to determine treatment progress and was recommended least for diagnosis alone. This can be explained by the fact that the diagnosis relies highly on the patient's clinical presentation aided by radiographic examination.

As mentioned previously, the AAE recommends limiting the use of CBCT to certain situations that are listed in the joint position statement (7). Of the 30 cases with CBCT, 29 (96.7%) fell within the AAE-R, which confirmed that faculty adhere to the recommendations when obtaining CBCT. These recommendations are those in which CBCT is the image of choice and not optional. The single case with CBCT that did not fall within the AAE-R was for a perforation that occurred during treatment. When the case was reviewed further, it could be considered that one case is related to locating a missed canal in a calcified tooth and in another case, it was taken to evaluate a non-healing sinus tract, which also can be used for pre-surgical planning. This brought the number of cases that fell within the AAE-R to 100%.

It also was noted that the most common type of case for which CBCT is recommended by the AAE-R, but was not taken, was non-surgical retreatment. This can be attributed to most faculty's experience in such cases, which allowed them to use the conventional 2D radiographs available. Another common reason for not using CBCT is

time constraints, particularly in cases in which CBCT would be recommended mid-treatment. Furthermore, cost also can be a factor in not recommending or using CBCT in many cases in which it would be beneficial.

Finally, we can conclude that faculty in the endodontics program adhere largely to AAE-R when recommending CBCT and do not over-prescribe it, but rather, under-prescribe it slightly, which was evident in the aforementioned analysis and also in the level of agreement, which was consistent with and without CBCT ($p < 0.05$).

This study's primary limitation was the number of cases selected for the study. The reason for this limitation was that we attempted to present all scans to reviewers using the same software and machine. The machine used was obtained in January 2015 and the cases were selected in December 2016. Another limitation was that general practitioners were not included as reviewers. When the literature was reviewed, we noted that more than one study about CBCT's efficacy used general practitioners.

Conclusion

Within the study's limitations, we can conclude that CBCT has a significant effect in determining the etiological factors that contribute to endodontic pathology (55% change overall) and making treatment recommendations (49% change overall). Further, CBCT is neither over- nor under-prescribed in the endodontic department and the faculty adhere largely to the AAE/AAOMR's recommendations. Further studies need to be conducted that include more cases and potentially categorize them according to complexity.

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