CLINICAL RESEARCH

The Recommendation of Cone-beam Computed Tomography and Its Effect on Endodontic Diagnosis and Treatment Planning

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ABSTRACT

Introduction: Although intraoral radiographs are foundational for diagnosis and planning treatment in dentistry, the resulting 2-dimensional image varies in interpretation requiring judgment. Cone-beam computed tomographic imaging provides a more detailed 3-dimensional image that may affect treatment recommendations. This study aimed to determine the basis for CBCT recommendations and the 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 1, all 45 cases were reviewed by 3 examiners without access to the CBCT scans. For phase 2, 4 months later, the 3 examiners reanalyzed the 30 cases, this time with the associated CBCT scan. Intra- and interexaminer agreements were recorded and analyzed. Also, the recommendations for CBCT were compared with the American Association of Endodontists/American Academy of Oral and Maxillofacial Radiology joint statement. **Results:** Interexaminer agreement in phases 1 and 2 was 65% and 72%, respectively. For endodontic diagnoses, there was a 19% change in the pulpal diagnosis category when CBCT imaging was added, whereas there was a 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 imaging was recommended 78.8% of the time when the case had a CBCT on record versus 33% of the time in cases without. **Conclusions:** CBCT imaging has a significant effect in determining the etiology of endodontic pathoses and in recommending treatment. Furthermore, CBCT imaging is not overprescribed in the endodontic department, and the faculty members adhere to the American Association of Endodontists/American Academy of Oral and Maxillofacial Radiology recommendations. *(J Endod 2019;■:1–7.)*

KEY WORDS

Agreement; cone-beam computed tomography; diagnosis; recommendation

SIGNIFICANCE

This study's goals were to determine whether or not CBCT imaging can provide additional useful information, and whether that information can be used to improve treatment planning when CBCT imaging is taken in accordance with the guidelines in the AAE/AAOMR joint statement.

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 pathoses and plan appropriate treatments. However, conventional radiography provides only a 2-dimensional image of a 3-dimensional object, and superimposition also can result in reduced diagnostic efficacy. In their study, Bender and Seltzer[2] found that periapical lesions do not show in a periapical radiograph until they reach the cortical bone adjacent to the tooth involved. Figure 1 is an example of the value of CBCT in showing a periapical radiolucency that could not be seen in a periapical radiograph.

Cone-beam computed tomographic (CBCT) imaging was introduced to dentistry in the United States after Food and Drug Administration 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, providing an immediate 3-dimensional radiographic image[3]. Accordingly, its use is increasing rapidly in endodontics. Several studies have been conducted to evaluate CBCT's efficacy in identifying endodontic pathoses and to compare this technology with

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conventional radiographic methods. A study designed to compare diagnostic accuracy in detecting a periapical lesion created artificially using CBCT imaging versus digital periapical radiography (PAR) found that CBCT imaging detected simulated lesions of different sizes and locations more accurately. The study also found that CBCT imaging 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 with intraoral 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].

CBCT imaging has been found to affect decision making in therapeutic endodontics significantly[6–8]. The American Association of Endodontics (AAE) released a joint statement with the American Academy of Oral and Maxillofacial Radiology (AAOMR) with respect to CBCT imaging and recommended its use in endodontics in many situations[9]. The statement is an evidence-based list of guidelines with respect to the best uses of CBCT imaging that is based on an extensive literature review. For example, the statement recommends using CBCT scanning 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; no fracture lines were detected with PAR, so CBCT scans were used. The results showed that CBCT imaging was 88% accurate in detecting VRFs[10]. However, in a study aimed to investigate the extent of cracks in teeth using PAR and CBCT imaging *in vitro*, neither CBCT imaging nor PAR was found effective in quantifying the extent of cracks in teeth[11].

Yi et al[12] performed a systematic review to compare the diagnostic accuracy of CBCT imaging and PAR in detecting external root resorption (ERR). The results indicated that CBCT imaging was significantly more sensitive than PAR, which makes it a reliable method to detect the presence of ERR.

A study by Schloss et al[13] showed that CBCT imaging evaluated periapical lesions and healing after endodontic microsurgery more precisely than PAR. However, Kruse et al[14] showed that 42% of the lesions CBCT imaging detected had no periapical inflammation but merely scar tissue, as histologic studies of the lesions acquired during resurgery confirmed.

CBCT imaging has also been recommended to identify missed anatomy or study a case of unique morphology before or midendodontic treatment[9]. A study conducted to determine whether CBCT scans can help locate second mesiobuccal 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 troughing[15]. Another study also indicated that CBCT imaging was no more able to identify complex root canal morphology in premolars than the gold standard (PAR)[16].

It is challenging for clinicians to identify certain radicular changes, such as perforations, root resorption, and VRFs. CBCT imaging has been recommended to increase accuracy in diagnosing such problems[9]. Based on Takeshita et al's study[17], CBCT imaging was recommended for the identification of ERR and VRFs because of its superior performance, whereas PAR was recommended for the diagnosis of root perforations because PAR emits less radiation and achieves similar performance as CBCT imaging[17].

There appears to be some conflict regarding the efficacy of CBCT imaging in different aspects of endodontics. Therefore, based on the literature review mentioned previously, this study investigated whether a preoperative CBCT scan changes treatment decisions significantly from preoperative PAR. This study's goals were to determine whether or not CBCT imaging can provide additional useful information and whether that information can be used to improve treatment planning when the CBCT scan is taken in accordance with the recommendations in the AAE/AAOMR's joint position statement. This study was also designed to achieve a better understanding of whether or not endodontic faculty adhere to the AAE recommendations when CBCT imaging is used.

MATERIALS AND METHODS

Deidentified electronic dental health records with CBCT scans were selected for this retrospective cohort study, and at least 1 faculty member in the endodontic department verified the appropriateness of and reason that all CBCT scans were prescribed. An application for exemption was submitted and approved by the institutional review board office before the study began. A code search query was performed using the electronic dental health record 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, root canal therapy, nonsurgical retreatment, and surgical root canal therapy. 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, sex, or medical condition and were categorized according to the reason the CBCT scan 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 1 identifier for each tooth because 4 cases involved 2 teeth, and each was considered a separate case, such that the final number of cases with CBCT scans 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[18]. The template included the patient's sex 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 imaging, 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 2.

In phase 2 of the study, the 30 cases from phase I were presented to all reviewers 4 months later together with their respective CBCT scans. All CBCT scans were reviewed using either Sedexis (Dentsply Sirona, Tulsa, OK) or I-Cat Vision (Kavo Kerr, Detroit, MI) 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 imaging, the answers were compiled for all cases and reviewers to measure the frequency with which CBCT scanning was prescribed. Whether it was for or against, each answer was compared with the actual implementation of CBCT imaging in the case. In addition, each

FIGURE 1 – (*A*) PAR of the maxillary left quadrant. The first molar showing no periapical changes. (*B*) The sagittal section showing both buccal roots with periapical radiolucency. (*C*) The sagittal section showing the palatal root with periodontal space widening.

case was categorized based on the AAE/AAOMR position statement to determine whether or not the scans followed its recommendations.

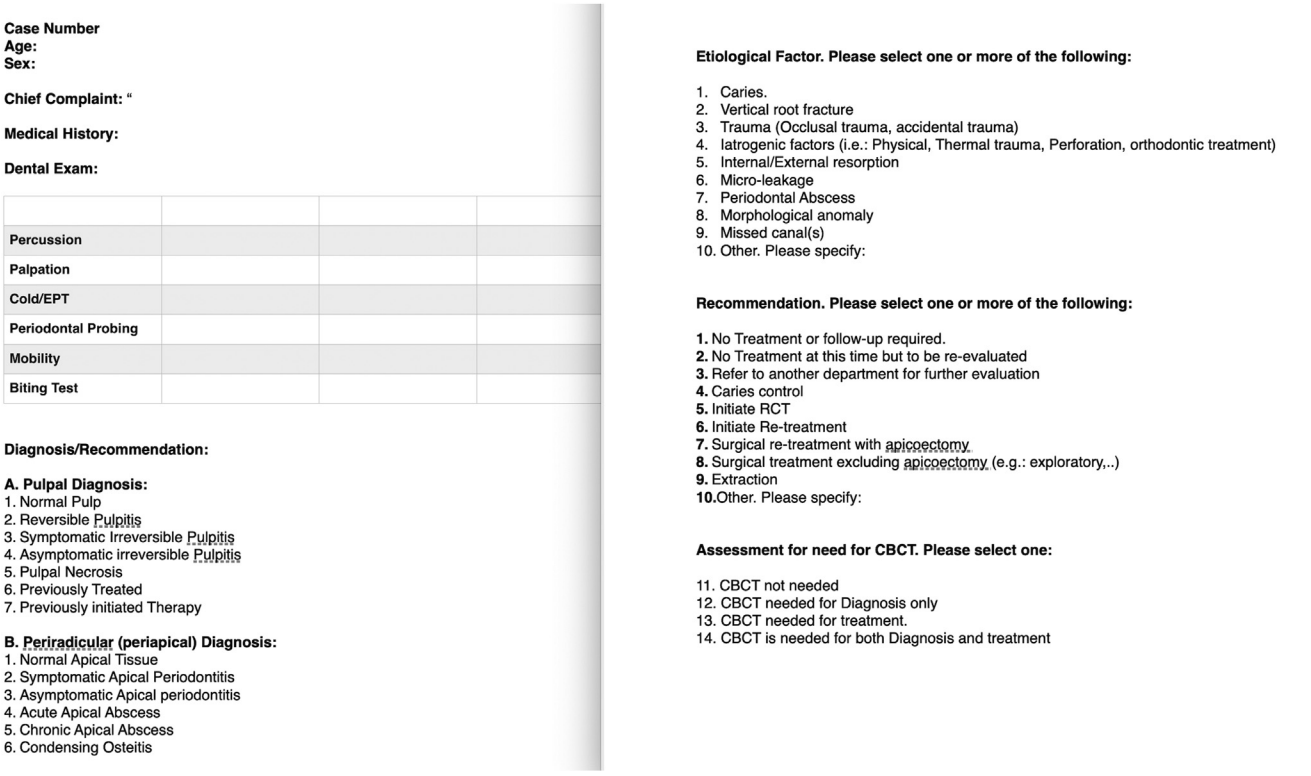
The Cohen kappa coefficient was used to assess agreement in ratings between phases 1 and 2 for each faculty reviewer. An overall agreement rate also was measured for all of the questionnaire categories.

Only the 30 cases with CBCT scans were included when the influence of CBCT imaging was evaluated. Each faculty member's answers were compared, and the data were analyzed using SAS software (SAS Institute Inc, Cary, NC). The first analysis compared each reviewer's individual answers with each question between phases 1 and 2 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 members' pulpal diagnosis (diagnosis A) with slight differences among reviewers. In the periapical diagnosis (diagnosis B) section, the change increased to 30%, with slight differences among reviewers. In the etiologic factor category, the difference increased drastically to 54.4%, with slightly more pronounced differences among faculty reviewers. Lastly, in the recommendation category, the change was 48.9%, and 1 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 scans.

When the degree of agreement was measured, it was found that the faculty tended to agree more when CBCT imaging was used. However, although it was clinically relevant, the



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 2 – An image of the template illustrating the way the cases were presented to the faculty reviewers in phases 1 and 2.

difference was not statistically significant ($P > .05$). The kappa test results were as follows: for diagnosis A, agreement improved from 0.68 to 0.70; for diagnosis B from 0.62 to 0.73; for the etiologic factor category from 0.42 to 0.44; and for the recommendation category from 0.36 to 0.39. The agreement improved notably overall when CBCT imaging was added to the diagnostic tools offered to the reviewers.

To evaluate the need of CBCT imaging in endodontics, the reviewers' responses were compared with its actual implementation. The data for this evaluation are summarized in Table 2.

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

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

When the recommendations for the need for CBCT imaging were compared with respect to whether the case fell under the AAE recommendations, all cases with a CBCT scan but 1 did so ($n = 29$, 96.6%). Cases with no CBCT scan that fell within the AAE recommendations ($n = 9$) constituted 60% of the cases with no CBCT scan ($n = 15$), whereas 40% ($n = 6$) of the cases without CBCT scans did not fall within the AAE recommendations. Table 3 shows a detailed analysis of the types of cases based on AAE recommendations.

TABLE 1 - Percentages of the Answers for Each Category That Remained Unchanged after the Cases Were Presented with Cone-beam Computed Tomographic Imaging

Category	Reviewer 1, % ($n = 30$)	Reviewer 2, % ($n = 30$)	Reviewer 3, % ($n = 30$)	*P* value for differences between revieweres	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

DIAG-A, pulpal diagnosis; DIAG-B, periapical diagnosis; ETIOL, etiologic factors; RECOMM, recommendation with percentages per individual faculty member of the answers that remained the same after the cases were presented with cone-beam computed tomographic imaging.

DISCUSSION

As mentioned previously, this study's goal was to measure CBCT imaging's effect on diagnosis and treatment decisions in endodontic cases. The results indicated that CBCT's use affected reviewers' choices when making pulpal and periapical diagnoses and more notably when determining etiologic factors and recommending a treatment. These findings are consistent with those of Rodriguez et al[7], who concluded that CBCT imaging had a direct influence on the treatment decisions dentists make, particularly general practitioners, and those of Ee et al, who concluded that CBCT imaging may affect the treatment plan in about 62% of cases[8].

CBCT imaging was the only modifier between phases 1 and 2, with the results of kappa tests confirming a significant increase in

TABLE 2 - Reviewers' Responses for All Cases Versus the Actual Implementation of Cone-beam Computed Tomographic (CBCT) Imaging

	CBCT scan not needed			CBCT scan needed for diagnosis only			CBCT scan needed for treatment only			CBCT scan needed for both treatment and diagnosis		
DMD	Responses	CBCT scan on record	NO CBCT scan on record	Responses	CBCT scan on record	NO CBCT scan on record	Responses	CBCT scan on record	NO CBCT scan on record	Responses	CBCT scan on record	NO CBCT scan 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

DMD, doctor of medicine in dentistry.

reviewer agreement in all categories when CBCT imaging was used. For example, the agreement on the asymptomatic apical periodontitis diagnosis improved significantly with the use of CBCT scanning. This finding confirmed that CBCT imaging improves the detection of asymptomatic apical lesions that conventional 2-dimensional radiographs do not detect. The study by Campello et al[4], which was designed to determine CBCT imaging's efficacy in detecting periapical lesions created artificially, concluded that CBCT imaging is more accurate in detecting such lesions, regardless of their size. A similar conclusion was drawn in another study by Liang et al[19]. This was confirmed in a prospective study by van der Borden et al[20] in which 21 additional periapical lesions were still detectable on the CBCT scan compared with PAR on 71 roots at recall.

Furthermore, the kappa test showed that the agreement in detecting VRFs as an etiologic factor improved significantly when CBCT imaging was used, which leads to the conclusion that CBCT scanning helps detect VRFs, possibly because of its ability to visualize bone loss patterns that are associated with VRFs in a 3-dimensional imaging model. The study by Saberi et al[10] regarding the detection of VRFs confirmed this, and another study by Metska et al[21] reported a similar conclusion. Furthermore, the inter-reviewer agreement improved significantly for the missed canal selection in determining the etiologic factor for the pathologic process. Thus, many studies have proven CBCT's ability to detect missed or calcified canals and complex morphology[15,22].

With respect to the selections in the need for CBCT section, the fact that in approximately 65% of the cases, 2 or more reviewers agreed on whether or not a CBCT scan 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 imaging 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 imaging to certain situations that are listed in the joint position statement[9]. Of the 30 cases with CBCT scans, 29 (96.7%) fell within the AAE recommendations, which confirmed that faculty adhere to the recommendations when obtaining CBCT imaging. These recommendations are those in which a CBCT scan is the image of choice and not optional. The single case with CBCT imaging that did not fall within the AAE recommendations was for a perforation that occurred during treatment. When the case was reviewed further, it could be considered that 1 case is related to locating a missed canal in a calcified tooth, and in another case, it was taken to evaluate a nonhealing sinus tract, which also can be used for presurgical planning. This brought the number of cases that fell within the AAE recommendations to 100%.

It also was noted that the most common type of case for which CBCT imaging is recommended by the AAE recommendations but was not taken was nonsurgical retreatment. This can be attributed to most faculty members' experience in such cases, which allowed them to use the conventional 2-dimensional radiographs available. Another common reason for not using CBCT imaging is time constraints, particularly in cases in which CBCT scanning would be recommended midtreatment. Furthermore, cost also can be a factor in not recommending or using CBCT imaging in many cases in which it would be beneficial.

Finally, we can conclude that faculty in the endodontics program adhere largely to AAE recommendations when recommending CBCT imaging and do not overprescribe it but rather underprescribe it slightly, which was evident in the aforementioned analysis and also in the level of agreement, which was consistent with and without CBCT imaging ($P < .05$).

TABLE 3 - A Detailed Breakdown of the Case Categories according to American Association of Endodontists (AAE) Recommendations and the Number of Cases within Those Categories

AAE-AAOMR CBCT guideline	Number of cases	CBCT scan on record	No CBCT scan 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/nonhealing lesion	8	6	2
Nonsurgical retreatment	8	2	6
Prosurgical 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

AAOMR, American Academy of Oral and Maxillofacial Radiology; CBCT, cone-beam computed tomographic.

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 1 study about the efficacy of CBCT imaging used general practitioners.

CONCLUSION

Within the study's limitations, we can conclude that CBCT imaging has a significant effect in determining the etiologic factors that contribute to endodontic pathosis (55% change overall) and making treatment recommendations (49% change overall). Furthermore, CBCT imaging is neither over- nor underprescribed 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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