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Efficacy of cone beam computed tomography use in endodontics

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THESIS

EFFICACY OF CONE BEAM COMPUTED TOMOGRAPHY USE IN ENDODONTICS

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ABSTRACT

Introduction: This study's aims were to: 1) evaluate whether or not there was a treatment plan change, if CBCT is used; and 2) evaluate if the use of CBCT as diagnostic tool improves the treatment outcome. **We hypothesized that** 1. the use of CBCT as diagnostic tool changes the treatment plan; and 2. improves the treatment outcome

Materials and Methods:

This was an IRB approved retrospective study of all the conventional re-treatments and surgical RCT performed at Boston University Post-doctoral clinic from 2009 - 2015. Of 10,836 cases completed, 674 cases had a CBCT on file and 31 had a pre- and post-CBCT treatment plan with at least 3 months follow up. Cases with CBCT were matched (2 to 1) with cases without CBCT based on patients' sex, age, tooth type, diagnosis, procedure performed, and insurance type. Chart notes and treatments were reviewed to identify

treatment plan changes. The investigator evaluated outcome as either Success/Survive/ Failure. Statistical Analyses tested for differences in treatment plan and Success/Survive/ Failure rates at minimum 3 months.

Result:

31 cases and 49 controls were evaluated. There were no differences in mean age (46) or insurance between cases and controls. In over half of the cases (54.8%) the treatment plan changed when CBCT was used. Cases with CBCT had 32% success rate, 60% survival rate and 8% failure rate at minimum 3 months whereas cases without CBCT had 22.4% success rate, 53.1% survival rate and 24.5% failure rate, p-value = 0.21.

Conclusion:

The use of CBCT as diagnostic tool affected more than half of the treatment plans. While CBCT appeared to improve the treatment outcomes, the difference in this small sample is not statistically significant. Future research will require larger sample sizes to test whether CBCT improves treatment efficacy in endodontics.

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Introduction:

Conventional radiography is an integral component of Root Canal Therapy. It is used prior to treatment to aid in diagnosis, during the root canal therapy to give feedback to the clinician, after the RCT to evaluate treatment prognosis, as well as in follow-up appointments to assess the treatment outcome. Conventional two-dimensional radiography has its limitations. It is a two dimensional illustration of a three-dimensional object. Further, anatomical superimposition makes it difficult to accurately assess lesions of endodontic origin or healing after treatment. A study done by Bender and Seltzer (1961) concluded that apical periodontitis will go undiagnosed during early stages of the disease.[1] In a study by Goldman, Pearson and Darzenta (1972) success and failure of 253 cases selected at random were determined by having six examiners read them. They agreed on only 47% of the cases. Upper molars gave the greatest percentage of disagreement, but all the other teeth gave large percentages of disagreement also. [2]

The introduction of maxillofacial Cone Beam Computed Tomography (CBCT) in 1996 provided the possibility of three dimensional (3D) imaging. CBCT captures a 3D volume of data in a single scan, and the raw data from each rotation are reconstructed to produce tomographic images in three anatomical planes of sagittal, coronal and axial. The size of

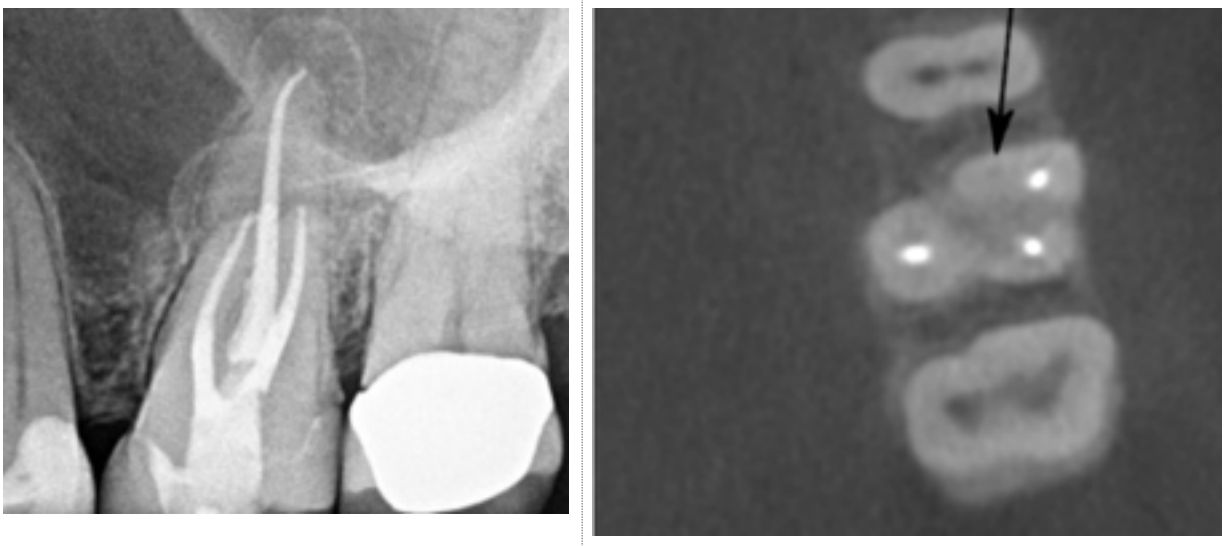
the field of view (FOV) can be variable. CBCT devices were divided into 4 subcategories: dentoalveolar (FOV <8 cm), maxillomandibular (FOV 8–15 cm), skeletal (FOV 15–21 cm), and head and neck (FOV >21 cm).

The effective dose of CBCT scanners may vary, but it can be the same as that of a panoramic dental x-ray and considerably less than that of a medical computed tomographic scan. The radiation dose can be reduced using a smaller FOV, fewer projections, and a bigger voxel size. Images acquired with big voxel sizes and then reconstructed at smaller voxel sizes may obtain similar qualities with reduced radiation doses. The radiation dose of the small-volume CBCT scanner is similar to 2–7 standard Periapical Radiographs (PRs), whereas the radiation dose of a large-volume scanner is similar to that of a full-mouth series of PRs. However, radiation dose is machine specific and can vary greatly. Radiation risk is age dependent, and beyond 80 years old, the risk becomes negligible because the latent period between x-ray exposure and the clinical presentation of tumors will probably exceed the life span of a patient. In contrast, tissues of young people are more radiosensitive, and their prospective life spans are likely to exceed the latent period. At all ages, risks for females are slightly higher than for males. [3]

CBCT is superior to conventional radiography in capturing the true root canal anatomy. [4]

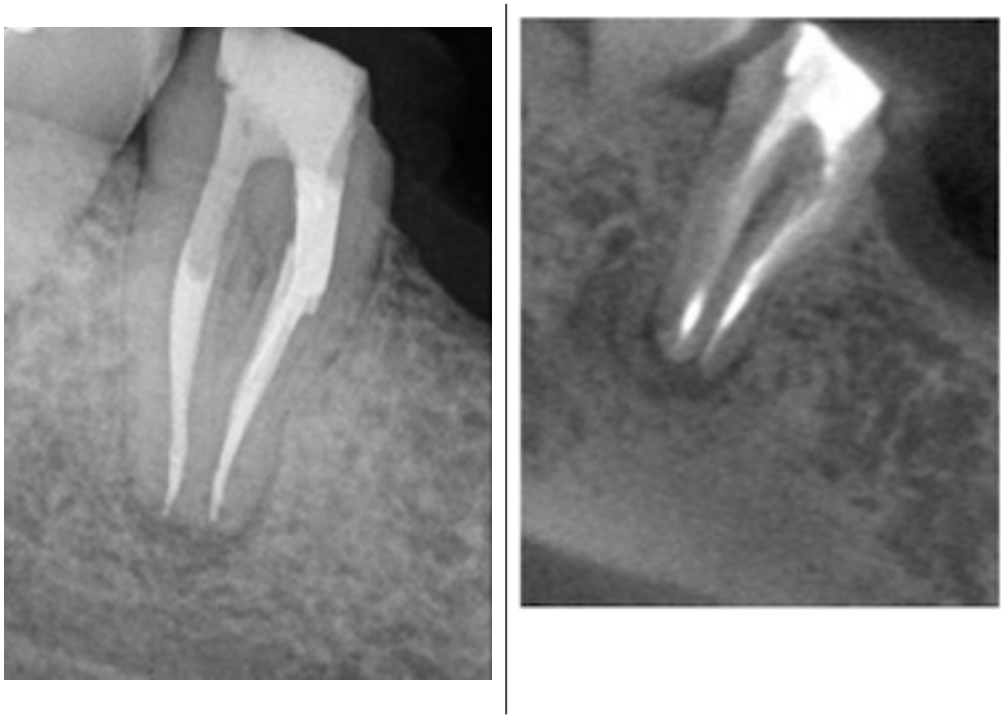
In a study by Michetti et al. there was a strong correlation between CBCT and histological sections of 9 molars.[5] Their findings suggest an increase in the reliability of CBCT in assessing the root anatomy compared with 2-D imaging.[6] (Figure 1). Periapical lesions are only detected on conventional radiography when the disease is in the advanced stage, and 2-D imaging still fails to show the depth of the lesion, relationship between the root and periodical lesion and thickness of the cortical and cancellous bone, whereas in CBCT [7] periapical lesions visualized in 3-D provide clearer anatomical detail which can lead to better outcomes.

Figure 1: PA (left) and CBCT (right) axial scan of upper molar with missed MB2 Canal



Due to anatomical superimposition, anatomical structures such as a sinus, mental foramen, nasopalatine foramen have a higher probability to be missed with conventional radiography. [8] By the same token, CBCT shows a lower healed and healing rate after conventional root canal therapy at one year follow-up studies compared to conventional radiography.[9] (Figure 2)

Figure 2: Healing evaluation based on PA (left) and CBCT (right) coronal scan



CBCT imaging is recommended for endodontic surgery planning. The accurate anatomical landmarks such as mandibular canals and sinus in relation to the tooth involved in the surgery can be clearly identified using CBCT. [10] According to Christiansen et al., the boney defect on Periapical radiography was approximately 10% smaller than on CBCT.[11]

Root fracture, resorption and perforation are other categories that AAE recommend use of CBCT for better diagnosis. The fracture is seen as a radiolucent line between the fragments and as a discontinuity of the periodontal ligament and unless displaced, root fracture is unlikely to be visualized on conventional radiography.[12] Horizontal root fractures are easier to detect than longitudinal. [13] And the higher the CBCT resolution, the higher the diagnostic accuracy. [14] However there is not a consensus on diagnostic capability of CBCT on vertical root fracture. [15] Internal and external resorptive defects spread in all directions within the root canal system and their size and location cannot be detected on conventional radiography. [16] Accurate diagnosis and treatment planning for complications such as root perforation are the key to prognosis. Conventional radiography fails to detect buccal and lingual perforation due to superimposition, and CBCT is superior in identifying perforation. [17]

In a joint statement by AAE and AAOMR,[18] the use of CBCT in Endodontics is recommended for diagnosis in patients who present with contradictory or nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth. AAE and AAOMR recommendations include the use of CBCT preoperatively in:

- Teeth with the potential for extra canals and suspected complex morphology, such as mandibular anterior teeth, and maxillary and mandibular premolars and molars; and in

- Dental anomalies.

AAE and AAOMR recommendations include the use of CBCT use of CBCT intraoperatively:

- For identification and localization of calcified canals.
- Nonsurgical Retreatment if clinical examination and 2-D intraoral radiography are inconclusive in the detection of vertical root fracture.
- Assessing endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.
- Evaluating the non-healing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical or extraction.
- Presurgical treatment planning to localize root apex/apices and to evaluate the proximity to adjacent anatomical structures.
- Diagnosis and management of limited dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures.
- The localization and differentiation of external and internal resorptive defects and the determination of appropriate treatment and prognosis.

However CBCT has limitations.

CBCT image quality and diagnostic capability is greatly affected by scatter and beam hardening caused by high density materials such as implants, crowns, posts, separated instruments, root canal filling materials, etc. Scatter and beam hardening can either imitate or hide endodontic origin diseases. [19]

Several studies have evaluated the use of CBCT as diagnostic tool. The purpose of this study was to evaluate whether or not there was a treatment plan change when CBCT is used, and also evaluate if the use of CBCT as a diagnostic tool improves the treatment outcome. We hypothesized that the use of CBCT as diagnostic tool changes the treatment plan and improves the treatment outcome.

Hypotheses:

1) H0: Use of CBCT as diagnostic tool does not change the treatment plan.

   H1: Use of CBCT as diagnostic tool changes the treatment plan.

2) H0: Use of CBCT as diagnostic tool has no effect the treatment outcome.

   H1: Use of CBCT as diagnostic tool improves the treatment outcome.

Materials and Methods:

This was an IRB approved retrospective study of all surgical and non-surgical root canal treatment performed at BU Post-doctoral clinic from 2009 - 2015. The limited database was kept on a HIPAA approved secure server and was only available to investigators approved by IRB at all times. The Limited Database of 10,836 cases was obtained from Information Technology by using the following codes.

- Root canal treatment: D3310, D3320, D3330
- Re-treatment: D3346, D3347, D3348
- Surgical root canal treatment: D3410, D3421, D3425.

The dataset included patients':

- Age
- Sex
- Medical history including stroke, heart problem, diabetes, hepatitis, AIDS, HIV, kidney disease, Tumor, Cancer, High blood pressure. Patients' medical history was considered significant if the answer to any above condition was yes.
- Dental insurance
- Race and ethnicity
- Tooth number

- Procedure code completed

Of the 10,836 cases 674 had CBCT on file. All 674 CBCTs were screened for the sample. We found 31 out of 674 cases that had records of pre- and post-CBCT treatment plan with at least 3 months follow up. These 31 cases were each initially to be matched with 5 cases out of 10,162 sample pool without CBCT based on patients' sex, age plus and minus 5 years, tooth number or the contralateral tooth, procedure code completed, and insurance type. Then, out of the 5 randomized matches, the PI selected the two mostly similar cases based on pre-operative pulpal and periapical diagnosis, pre-operative radiographs to determine anatomical challenges, and pre-operative endodontics prognosis as favorable, questionable or unfavorable and used them as controls. Six out of 31 cases did not have any match and 1 had only had 1 match. (Table 1 and Table 2)

Consultation notes and treatments notes were reviewed for cases with CBCT to identify treatment plan changes. (Table 3)

The investigator evaluated outcome as success, survival and failure of treatment for both groups: cases with CBCT and the control group. All cases were de-identified and were only used for the purpose of this research. Random case numbers were assigned to the selected study subjects.

Table 1: Cases with CBCT

Case Number	Tooth Number	Gender	Age	Medical History	Procedure Code	Insurance	Re-call Period in months	Outcome
1	5	F	72	Yes	D3346	PVSLF	9	2
2	30	M	29	Yes	D3330	PVSLF	21	2
3	3	F	48	No	D3330	PVSLF	4	1
4*	30	F	46	Yes	D3348	GOVT	6	0
5	30	F	52	Yes	D3330	PVSLF	15	0
6*	9	M	46	No	D9310	GOVT	0	2
7	9	F	68	Yes	D3346	PVSLF	9	1
8	10	F	68	Yes	D3310	GOVT	9	1
9	19	M	27	No	D3425	GOVT	15	1
10	20	M	52	Yes	D3320	GOVT	23	1
11	18	F	40	Yes	D3330	GOVT	3	1
12	2	M	23	No	D3330	GOVT	52	1
13*	28	M	52	Yes	D3421	GOVT	7	2
14	14	F	50	Yes	D3330	PVSLF	4	1
15	30	M	48	Yes	D3330	GOVT	23	2
16	10	F	42	Yes	D3310	GOVT	9	1
17	13	M	48	Yes	D3320	PVSLF	5	2
18	12	F	55	Yes	D3320	PVSLF	16	2
19	19	M	45	Yes	D3330	GOVT	13	1
20	3	F	47	Yes	D3330	PVSLF	14	1
21**	4	M	53	Yes	D3320	PVSLF	11	1
22	9	M	51	Yes	D3310	GOVT	3	0
23	9	F	34	No	D3310	GOVT	4	2
24*	29	M	32	No	D3347	GOVT	28	1
25	4	M	67	Yes	D3320	PVSLF	3	1
26*	8	M	45	Yes	D3310	PVSLF	3	2
27*	9	M	45	Yes	D3310	PVSLF	3	2
28	29	F	23	No	D3320	GOVT	8	1
29	30	F	30	Yes	D3330	PVSLF	8	1
30	10	F	41	Yes	D3310	GOVT	9	2
31	11	M	60	Yes	D3320	PVSLF	3	1

Table 2: Control Cases Without CBCT

Case Number	Tooth Number	Gender	Age	Medical History	Procedure Code	Insurance	Re-call Period in months	Outcome
1	29	F	54	Yes	D3320	GOVT	12	0
2	29	F	58	Yes	D3320	GOVT	18	1
3	12	F	56	Yes	D3347	PVSLF	4	2
4	12	F	52	Yes	D3347	PVSLF	7	0
5	31	F	67	Yes	D3330	GOVT	9	2
6	18	F	69	Yes	D3330	GOVT	14	1
7	19	F	46	Yes	D3330	GOVT	14	1
8	19	F	47	Yes	D3330	GOVT	6	2
9	2	F	42	NO	D3330	GOVT	11	1
10	15	F	48	Yes	D3330	GOVT	4	0
11	14	M	61	Yes	D3330	PVSLF	16	1
12	14	M	55	Yes	D3330	PVSLF	7	1
13	14	M	33	NO	D3330	PVSLF	3	1
14	3	M	32	NO	D3330	PVSLF	8	2
15	30	F	62	Yes	D3348	GOVT	4	0
16	19	F	57	Yes	D3348	GOVT	8	1
17	7	M	60	Yes	D3310	PVSLF	13	1
18	7	M	58	Yes	D3310	PVSLF	5	0
19	12	F	47	Yes	D3320	PVSLF	12	1
20	12	F	52	Yes	D3320	PVSLF	16	1
21	30	M	50	Yes	D3348	PVSLF	24	2
22	30	M	43	Yes	D3348	PVSLF	48	0
23	3	F	41	NO	D3330	PVSLF	10	1
24	3	F	38	Yes	D3330	PVSLF	18	1
25	13	F	41	Yes	D3320	PVSLF	27	0
26	4	F	47	Yes	D3320	PVSLF	24	1
27	8	M	27	NO	D3310	GOVT	12	0
28	8	M	29	NO	D3310	GOVT	12	1
29	9	M	23	NO	D3310	GOVT	36	1
30	9	M	29	Yes	D3310	GOVT	48	1
31	29	F	46	Yes	D3320	GOVT	6	0

Table 2: Control Cases Without CBCT- continue

Case Number	Tooth Number	Gender	Age	Medical History	Procedure Code	Insurance	Re-call Period in months	Outcome
32	20	F	48	Yes	D3320	GOVT	12	1
33	19	F	41	Yes	D3330	GOVT	11	1
34	19	F	40	Yes	D3330	GOVT	14	1
35	7	M	17	NO	D3310	GOVT	9	2
36	7	M	15	NO	D3310	GOVT	8	0
37	19	M	54	Yes	D3330	GOVT	31	1
38	30	M	50	Yes	D3330	GOVT	14	2
39	8	M	47	Yes	D3346	PVSLF	42	1
40	9	M	46	Yes	D3346	PVSLF	21	1
41	7	M	45	Yes	D3310	PVSLF	6	1
42	10	M	47	Yes	D3310	PVSLF	24	1
43	9	M	25	NO	D3310	PVSLF	12	2
44	8	M	32	Yes	D3310	PVSLF	12	2
45	11	F	44	Yes	D3310	PVSLF	6	2
46	11	F	48	Yes	D3310	PVSLF	6	0
47	8	F	57	Yes	D3310	GOVT	7	2
48	4	M	58	Yes	D3347	PVSLF	12	1
49	13	M	68	Yes	D3347	PVSLF	6	2

***Cases without Match** ****Case with only one match** **0: Failure 1:Success 2:Survival**

Outcomes were defined and modified to include survival group based on Strindberg[20] criteria as follows:

1. Success:

- Absence of clinical signs or symptoms
- Absence of periapical radiolucency (disappearance of initial radiolucency, no new radiolucency developed)

Table 3: Pre and Post CBCT Treatment Plan

Case	Tooth	Clinical Exam and PA Findings	CBCT Findings	Tx-Plan Changed
1	5	Symptomatic/ Previously treated	Post Perforation	Yes
2	30	Perforation	Perforation	No
3	3	Periodontal Pocket/ J-shape lesion	Vertical Root Fracture	No
4	30	Periodontal Pocket/ Apical Lesion	Vertical Root Fracture	Yes
5	30	Symptomatic/ Odontogenic lesion	Non Odontogenic lesion	Yes
6	9	Resorption	Perforating Resorption	Yes
7	9	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	No
8	10	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	No
9	19	Previously treated/ Apical Periodontitis	Missed Canal	Yes
10	20	Undetectable source of pain	Sinisitus	Yes
11	18	Internal Resorption	Perforating Internal Resorption	Yes
12	30	Anatomical Variation	Entomolaris	No
13	28	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	No
14	14	Previously treated/ Apical Periodontitis	Vertical Root Fracture	Yes
15	30	Previously treated/ Apical Periodontitis	Vertical Root Fracture	Yes
16	10	Undetectable source of pain	Non Odontogenic lesion	Yes
17	13	Vertical Root Fracture	Inadequate previous treatment	Yes
18	12	External Root resorption	External Root resorption	Yes
19	19	Non Odontogenic source of pain	Non Odontogenic source of pain	No
20	3	Residual Cyst	Residual Cyst	No
21	4	Residual Cyst	Residual Cyst	No
22	9	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	No
23	8	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	No
24	29	Lip numbness/ Previously treated	Proximity to Mental Foramen	Yes
25	4	Previously treated/ Apical Periodontitis	Previously treated/ Apical Periodontitis	Yes
26	8	Previously treated/ Apical Periodontitis	Perforating lesion	Yes
27	9	Anatomical Structure	Fracture of Buccal Plate	Yes
28	29	External Root resorption	External Root resorption	No
29	30	Previously treated/ Apical Periodontitis	Missed Canal	Yes
30	10	Anatomical variation	Dents Invaginatus	No
31	11	External Root resorption	External Root resorption	No

- Absence of untoward events (extraction, re-treatment, apical surgery)

2. Survival:

- Absence of clinical signs or symptoms (regardless of radiographic condition)
- Absence of untoward events (extraction, re-treatment, apical surgery)

3. Failure:

- Presence of clinical signs or symptoms (regardless of radiographic condition)
- Occurrence of untoward event (extraction, re-treatment, apical surgery)

The percentage of treatment plans that changed was calculated. Survival Analyses evaluated the efficacy of CBCT use in Endodontics and power calculation were done to evaluate the strength of the study.

Results:

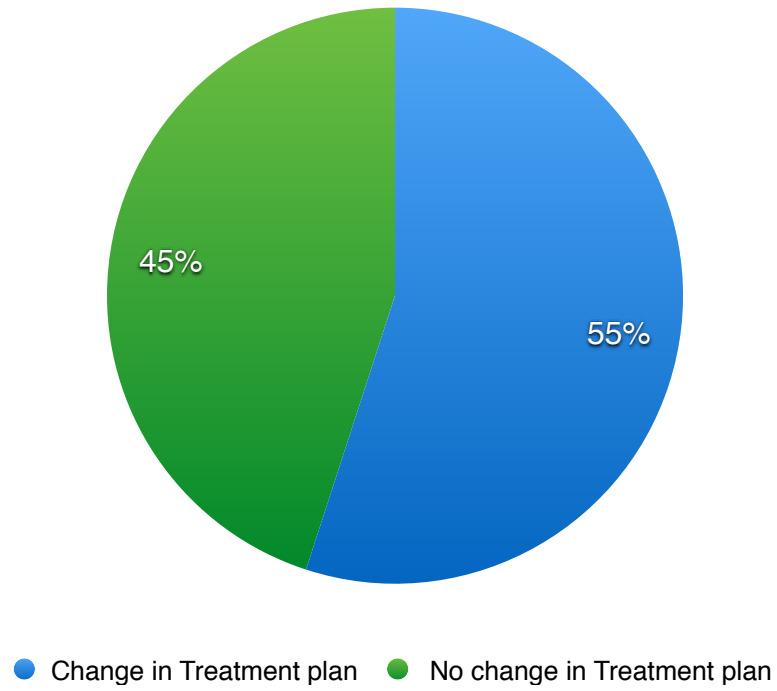
Comparison between CBCT and Periapical Radiographs in treatment planning :

The periapical radiographic diagnosis and clinical findings were compared to CBCT findings. Out of 31 cases; 10 anterior, 9 premolar and 12 molar teeth; with treatment plan prior and post CBCT, 17 had a change in treatment plan once the CBCT was reviewed. Changes in treatment plans were present in 4 anterior teeth, 6 premolar teeth and 7 molar teeth. The overall percentage change in treatment planning was 55%. (Table 4 and Figure 3). The majority of changes in treatment plan were in the premolar and molar region. Anatomical superimposition in posterior regions can be the reason for these findings.

Table 4: Change in Treatment plan based on CBCT

	Total number of cases	Change in treatment plan	Percentage change
Anterior	10	4	40%
Premolar	9	6	66.7%
Molar	12	7	58.3%
Total	**31**	**17**	**55%**

Figure 3: Percent change in endodontic treatment plan after CBCT Imaging



Efficacy of CBCT as diagnostic tool in endodontics treatment outcome:

Outcome of the treatments are either success, survival or failure based on Strindberg criteria. Out of 31 cases with CBCT and with minimum 3 months recall, 3 cases failed, 11 survived and 17 succeeded. However, 6 out of 31 cases did not have any match and are not included into our analysis. From the control group of 49 cases, 12 failed, 26 survived and 11 succeeded. The overall success/survived rate is 92% for the cases with CBCT and 75.5% for control group. P-value of 0.2111 is obtained when there are three possible out-

comes of failure, survive and success. Where success was the favorable outcome and the mean differences of two groups of cases were CBCT and control cases were compared, the p-value improved to 0.0867 when cases with success and survived were combined as favorable outcomes. However the Null Hypothesis is rejected since p-Value is bigger than 0.05. Table 5 summarizes these findings.

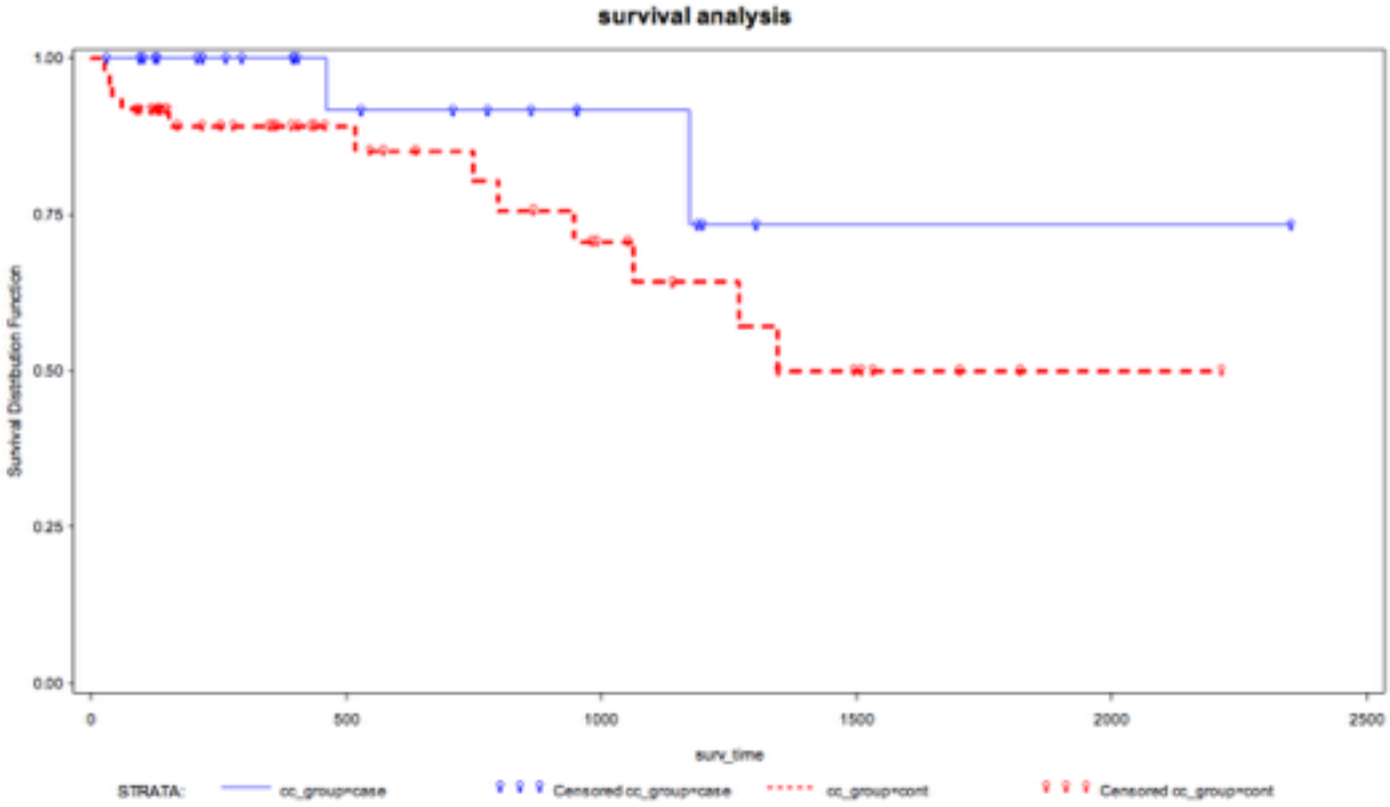
Survival Analysis is generally defined as a set of methods for analyzing data where the outcome variable is the time until the occurrence of an event of interest. In this study, number of days in recall were plotted against occurrence of the outcome. (Figure 4) The blue line represents cases with CBCT and each recall time of an individual case is shown by a blue dot. The red line represents the control group and each recall time of an individual control case is shown by a red dot.

The survival analysis graph demonstrates that at any point in time cases with CBCT survived/Succeeded longer than cases without CBCT.

Table 5: Outcomes Assessment of Endodontic Cases Based On Type of Diagnostic Imaging Utilized During Treatment

Outcome	CBCT Cases	Control Cases	P-Value
Failure	8%	24.50%	
Survive	60%	53.10%	0.2111
Success	32%	22.40%	
Failure	8%	24.50%	
Combined Survival and Success	92%	75.50%	0.0867

Figure 4: Survival Analysis



Discussion:

In this study we hypothesized that use of CBCT as diagnostic tool changes the treatment plan. Out of 31 cases with detailed chart notes specifying pre and post CBCT treatment plan, we found 17 cases with change in treatment render to the patient, for a total change of 55%. The majority of the changes in treatment plan were when premolar and molar teeth were involved. The extend of a resorption, missed canals and true size of an odontogenic lesions are some examples of where clinicians changed their treatment plan. This can be explained by more anatomical structures and thicker cortical plate in the posterior regions. Changes in more than half of the treatment plans in our study, is in agreement with study done by Ee et al.[21] A comparison of 30 endodontic diagnosis and treatment planning decisions using CBCT versus PA radiography was done by three endodontists. They concluded that 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.

We also hypothesized that use of CBCT as diagnostic tool improves the treatment outcome. The follow up time for all cases varies from 3 to 48 months. This is a retrospective study and the wide range of follow up is dictated by the available data.

Cases with CBCT had a combined success/survived rate of 92% whereas the control

group had a combined 75.5% success/survived rate. This rate is significantly lower than other outcome studies. The Toronto Study[22] reported 95%, 93% and 91% success/survival rate for root canal, re-treatment and surgery respectively. Our lower outcome rate can be explained by limited follow ups, presence of lesions, lack of timely coronal restorations, as well as case complexity and treatment planning based on PA only.

The difference between success/survived cases with CBCT vs. controls are not statistically significant (p-value >0.05); however it is clinically important and relevant. Diagnostic information directly influences treatment planning and clinical decisions. Accurate data leads to better treatment decisions and potentially more predictable outcomes. [23]

Limitations:

This is a retrospective study and the sample size is restricted to the data already available. Originally 674 cases with CBCT were found. However due to lack of complete documentation, follow up, and matching process, only 25 cases were included with 49 control cases.

This study's findings are clinically relevant and a power analysis is calculated to determine the number of cases needed to make the study statistically significant. This analysis shows that in order to accept the null hypothesis we need 78 cases with CBCT. (Table 6)

Table 6: Power Analysis, Pearson Chi-square Test for Two Proportions

Distribution	Asymptotic normal
Method	Normal approximation
Null Proportion Difference	0
Group 1 Proportion	0.08
Group 2 Proportion	0.245
Nominal Power	0.8
Number of Sides	2
Alpha	0.05
Computed N Per Group	
Actual Power	0.804
N per Group	**78**

Conclusions:

1. Within in the limitations of the present study, use of CBCT as diagnostic tool changed the treatment plan in more than half of the cases.

2. There is no statistically significant difference between conventional radiography and CBCT imaging in improving the treatment outcomes of endodontic cases. This may be due to limited sample size and future studies with larger sample size will determine the statistical and clinical significance of the difference.

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