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RESEARCH ARTICLE

Computed tomography (CT) in the selection of treatment for root-filled maxillary molars with apical periodontitis

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Objectives: The aims of this study were to evaluate whether the use of CT facilitates agreement among endodontists in selecting treatments for root-filled maxillary molars with apical periodontitis and to assess the efficacy of CT in choosing a treatment for such teeth.
Methods: 39 root-filled maxillary molars from 34 patients with suspected apical periodontitis were independently evaluated by 4 endodontists and 1 postgraduate student (decision-makers). Treatment decisions were made based on intra-oral radiographs and a fictive clinical history. After 1–3 months, the same decision-makers repeated the examination of the same teeth but with additional information from a CT examination. Agreement between decision-makers with or without the availability of the CT results was measured with Cohen's kappa coefficient. Differences in selected treatments with or without accessibility to the CT results were plotted for the same endodontists using descriptive statistics.
Results: The agreement in assessments among endodontists was slight or fair before the CT results were available (range: 0.081–0.535). No increase was observed after reviewing the CT results (range: 0.116–0.379). After the use of CT, the treatment plan was changed 38–76% of the time by all decision-makers, and the changes affected 57.8% of the cases in the study.
Conclusions: The endodontists in this study exhibited a low degree of agreement when choosing a treatment for root-filled maxillary molars with apical periodontitis. A CT examination of the investigated teeth did not result in a significantly higher degree of agreement, and CT frequently contributed to a shift in the selected therapy.
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Introduction

The use of CT technologies, CT and especially CBCT, has rapidly become widespread in contemporary endodontics. Reviews based on a hierarchical model developed by Fryback and Thornbury[1] have revealed that the majority of research regarding CT or CBCT in endodontics mainly concerns the technical efficacy and diagnostic accuracy efficacy.[1–3] The scientific evidence is limited, but systematic reviews support the notion that CT technologies are more sensitive than periapical radiographs for the detection of apical periodontitis.[2–4] Still, the use of a more accurate diagnostic technology does not necessarily lead to a different course of action or a better outcome. According to the hierarchical model, evidence from studies of higher levels of efficacy is needed

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to justify the general use of new diagnostic methods in the patient management process. These higher level efficacy studies should include investigations of whether the information produces change in the dentist's diagnostic behaviour and affects the patient management plan (Levels 3 and 4). The highest efficacy level studies eventually concern effects on patient outcomes and analyses of economic and societal costs and benefits (Levels 5 and 6). Few studies have investigated the impact of CT or CBCT on endodontics, when making a diagnosis or selecting a treatment option, and most importantly, even lesser studies have assessed the benefit to the patient of using these imaging modalities.[2,3] As a result, the evidence is still inconclusive whether the use of CT or CBCT is warranted in the clinical decision-making and treatment of the individual patient.[2,3]

Endodontically treated teeth are frequently associated with periapical inflammatory lesions.[5] Several factors such as clinician preferences and experience in performing certain therapies, as well as the both practitioner and patient values, may influence the clinical decision-making for apical periodontitis in root-filled teeth.[6] Consequently, several investigations have revealed considerable clinical variations in the management of root-filled teeth with apical periodontitis.[6–8] One factor that may influence the management is the diagnosis of the lesion itself. However, the interpretation of the periapical status based on intra-oral radiographs is hindered by substantial observer variation.[9] CT and CBCT provide images of higher diagnostic accuracy and potentially clinically valuable information for the diagnosis and clinical decision-making of periapical pathology, particularly in the maxilla.[10–12] Therefore, hypothetically, the interobserver variation in clinical decision-making for maxillary molars with apical periodontitis would decrease, if such information were available.

In a previously published article, CT was found to provide potentially important information for the retreatment decision-making process of root-filled teeth with apical periodontitis in maxillary molars.[10] CT images revealed periapical lesions in 38 (97%) teeth compared with 33 (85%) teeth on periapical radiographs. Also, the CT scans revealed the presence of an unfilled mesiolingual canal (MB2) in 27 (69%) teeth, of which 22 roots were associated with a periapical lesion.

The aim of the present study was to evaluate whether the use of CT facilitates agreement among endodontists in selecting treatments for root-filled maxillary molars with apical periodontitis. Another aim was to evaluate to what extent additional information from a CT might change therapeutic decisions.

Methods and materials

The study protocol was approved by the Regional Ethical Review Board in Gothenburg, Sweden.

Patients and teeth

This study population was the same as that in a previous investigation by Huumonen et al.[10] Patients referred to the University Clinic of Endodontics, Public Dental Health Service, Gothenburg, Sweden, during the year 2005 with a preliminary diagnosis of apical periodontitis in conjunction with a root-filled maxillary molar were consecutively included. After undergoing a preliminary clinical examination by an endodontist and providing informed consent to participate, the patients were examined at the University Clinic of Oral and Maxillofacial Radiology. A total of 34 patients (19 females and 15 males) with a mean age of 51 years (range: 19–84 years) were enrolled. Five patients had two neighbouring teeth that were both included in the study. Therefore, the study consisted of 39 maxillary molars (31 first and 8 second molars).

Radiographic examination

Two intra-oral periapical radiographs were taken at a 10° horizontal angle difference using a paralleling technique. Exposures (0.5–1.0 s) were made with a dental X-ray unit (Oralix® DC; Gendex Corporation, Milwaukee, WI) operated at 65 kV and 7.5 mA. The film, Kodak Insight film (Eastman Kodak, Rochester, NY), was processed according to manufacturer instructions. One patient who experienced difficulties in tolerating intra-orally placed films was examined with a dental scanogram (Scanora®; Soredex, Helsinki, Finland). Immediately after the radiograph, an axial CT was taken from the marginal bone crest to the hard palate using a four-channel multislice LightSpeed® QX/i CT (GE Medical System, Milwaukee, WI) operated at 120 kV, 50 mA and an exposure time of 1.0 s per rotation. In cases of thick metallic posts, some scans were performed further apically to decrease the influence of metallic artefacts. Reconstruction was performed with the "bone" algorithm with edge enhancement, giving 12–24 slices, with a thickness of 1.25 mm and a pixel size of 0.26 mm. The field of view was 13.4 cm.

Assessments

Assessment before CT: Four endodontists with 3–25 years' experience and one postgraduate student in endodontics participated in the study as decision-makers. The periapical radiographs were mounted in transparent frames, placed on a light box and analyzed with the aid of a viewer providing 2× magnification. All cases were presented with the same fictive clinical history:

> This patient is 45 years old and claims to be perfectly healthy. He was referred to you from his general dental practitioner to assess apical periodontitis in the current root-filled maxillary molar. The patient saw his general dental practitioner for tenderness and slight pain in the region. At the time of the examination, there were no subjective or clinical symptoms. All root canals and prosthetic reconstructions are at least 5 years old. No

other dental care, except for possible treatment for the current maxillary molar, is indicated or planned.

The decision-makers chose a treatment option for each root of the maxillary molar in question. The available options were no treatment, orthograde retreatment, surgical retreatment and root resection (extraction).

Assessment after CT: After 1–3 months, each decision-maker re-evaluated each case. At this point, in addition to the fictive clinical history and the intra-oral radiographs, they also had access to the results of the CT. A radiologic report that was written by two radiologists accompanied each case. A specialist in oral radiology assisted in examining the CT scans and guided the decision-maker in order to get availability to every slice in each case. The scans were interpreted on an IDS5 workstation (Sectra, Linköping, Sweden) using two RadiForce™ G21 monochrome liquid crystal display monitors (Eizo Nanao Corp., Ishikwa, Japan). The resolution of the monitors was 1600 × 1200 pixels. No additional program was used to elaborate the scans. A "true" radiological diagnosis was established for each case, and the decision-makers chose a post-CT treatment option for each root without knowing what they had selected in the "before" assessment.

All assessments (before and after CT) were performed independently.

Analysis

Each root was given a score of 1–5 depending on the level of invasiveness of the intervention: 1, no treatment; 2, orthograde root canal treatment; 3, retrograde root canal treatment; 4, root resection; and 5, extraction (if all roots were to be resected). The results were expressed at the tooth and patient levels. The treatment reported for each tooth or patient was determined by the highest score for any root of the tooth in question.

To analyze the interdecision-maker variation and the variation between the before and after assessments, we used Cohen's kappa coefficient with the following definitions of agreement: <0.00, poor; 0.00–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect.[13]

Results

Decision-maker I did not assess three cases in the before CT assessments, and decision-maker V did not report on one case in the after CT assessment, resulting in a total of 166 assessments of 191 teeth.

Agreement between decision-makers

Cohen's kappa coefficient between the decision-makers measured at the patient level in selecting the treatment option was slight or fair (range: 0.00–0.40) for each pair for both modalities (before and after CT), except between decision-makers I and V before CT (0.535), where the coefficient was moderate. The variation was between 0.081 and 0.535 before CT and between 0.116 and 0.379 after CT (Table 1).

Agreement between assessments before and after CT

Cohen's kappa coefficient between assessments before and after CT for the same decision-maker at the patient level varied between 0.142 and 0.467. Cohen's kappa coefficient for all assessments of all decision-makers before and after CT (n = 166) was 0.234 (Table 2).

Changes in the treatment plan after CT

The suggested treatment was modified in 57.8% of the cases (52.9% of all teeth). The variation among decision-makers ranged from 38 to 77% (36–66% of all teeth) (Table 3).

When the treatment plan was changed after CT, it was towards a more invasive treatment (higher score) in 68 assessments. A lower score was suggested in 28 assessments. The option of no treatment was chosen in 33 assessments by all decision-makers before CT (43 teeth) and in 16 assessments (25 teeth) after CT. In 10 assessments (18 teeth), the no-treatment option was selected both before and after CT.

Discussion

The acquired radiological images we used in this study have previously been evaluated in a study aiming to compare diagnostic information and radiation dose between intra-oral radiography and CT.[10] In our present study, presenting only new data, we exposed five clinical decision-makers, in a before/after additional diagnostic information design study. The main findings were that: (1) the endodontic decision-makers exhibited a low degree of agreement when choosing a treatment for root-filled maxillary molars with apical periodontitis; (2) a CT examination of the investigated teeth did not result in a significantly higher degree of agreement;

Table 1 Cohen's kappa coefficient between pairs of decision-makers (I–V) for both assessment modalities at the patient level

	II		*III*		*IV*		*V*	
Decision-makers	*Before CT*	*After CT*	*Before CT*	*After CT*	*Before CT*	*After CT*	*Before CT*	*After CT*
I	0.081 (n = 31)	0.199 (n = 34)	0.113 (n = 31)	0.184 (n = 34)	0.197 (n = 31)	0.215 (n = 34)	0.535 (n = 31)	0.116 (n = 33)
II	–	–	0.289 (n = 34)	0.222 (n = 34)	0.230 (n = 34)	0.379 (n = 34)	0.018 (n = 34)	0.195 (n = 33)
III	–	–	–	–	0.231 (n = 34)	0.231 (n = 34)	0.241 (n = 34)	0.189 (n = 33)
IV	–	–	–	–	–	–	0.311 (n = 34)	0.300 (n = 33)

Table 2 Cohen's kappa coefficient between the assessments before and after CT at the patient level for the same decision-maker

I	*II*	*III*	*IV*	*V*	*Total*
0.211 (n = 31)	0.133 (n = 34)	0.467 (n = 34)	0.245 (n = 34)	0.142 (n = 33)	0.234 (n = 166)

(3) CT frequently contributed to a shift in the selected therapy.

A similar research methodology has been used by several authors to evaluate the efficacy of diagnostic methods at the time of selecting a treatment plan.[14–17]

Changing the treatment plan after receiving additional information does not necessarily result in a positive outcome for the patient, and this is a subject that should be explored in randomized controlled trials. Such studies are difficult to perform and are uncommon in imaging studies for endodontics.[2,3] However, it is obvious that no improvement in patient outcome can be expected, if there is no change in the course of action following more sensitive radiological examinations.

The results and conclusions presented in a study such as ours should be interpreted cautiously.

It is important to emphasize that in before and after studies, there is no direct comparison between two different radiographic methods. Treatment decisions made after the use of an add-on technology (in this case, CT for root-filled maxillary molars) should be compared with those made with access to all previously available data, including clinical information.[18] One of the strengths of this study is that it utilized a consecutive population with a well-defined clinical problem. The study attempted to depict a real clinical situation with a fictive history similar to that found in an endodontist's clinical practice. However, contact with individual patients is lacking, and the fictive history was identical for all cases, which obviously reduces the external validity of the results. However, the use of this fictive scenario is practical and provides some control of the many variables that influence treatment decisions in a real clinical situation.[6]

Another strength of our study was the fact that the intra-oral radiographs and CT scans were performed almost simultaneously to eliminate the risk of maturation bias, which can be a disadvantage in before and after studies.[19]

We used Cohen's kappa coefficient to assess the variation between before and after assessments.

The treatment options were presented on a number scale that was not strictly ordinal in nature. However, from the patient and the clinician point of view, there was a certain gradation in treatment options from non-invasive (no therapy) to most invasive (extraction).

The agreement among decision-makers in selecting treatment options for root-filled maxillary molars with apical periodontitis was slight or fair despite the use of CT, which reduced the diagnostic variation. No trend could be observed. Factors other than diagnosis could also be important at the time a treatment plan is selected. Clinician preferences and experience in performing certain therapies, as well as both practitioner and patient values, will influence endodontic treatment planning, but none of those factors were targeted in this study.[6]

Cohen's kappa coefficient shows slight or fair correlation between the before and after assessments for the same decision-maker, except for decision-maker III, where the correlation was moderate. If the CT did not have any effect on the choice of treatment, Cohen's kappa measures would be close to 1 for each decision-maker. Since this was not the case, these results suggest that the CT examination affected the choice of treatment. The percentage of change is in the same high range as that found in a previous study on CBCT.[20] However, we did not measure the decision-maker variation with time, and this could have some influence on the results.

The results of this study show that CT led to changes to therapies that were usually more invasive. This is in agreement with the work by Mota de Almeida et al[20] on the use of CBCT in endodontics, which reported the same trend towards more invasive treatment with CBCT in endodontics. There is a possible risk of overdiagnosing when using CBCT.[21] One should be cautious when using and interpreting the results of a CBCT or CT scan because some of the diagnosed lesions might not represent pathological conditions. It has been reported that a clinician felt retrospectively that CBCT information led to therapies that were not in the patient's best interest.[20]

The data presented in the present study are from 2005, when CBCT was not as widely available as it is today. When using the correct protocol for CT, one could use a radiation dose that is comparable with that of CBCT.[22] However, for endodontic purposes, CBCT has the advantage of producing smaller fields of view and much higher resolution, resulting in a smaller

Table 3 Suggested treatment at the patient level before and after CT for all decision-makers for 34 patients

	After CT					
Before CT	*1*	*2*	*3*	*4*	*5*	*Total*
1	10	2	12	0	9	33
2	2	21	13	0	5	41
3	3	14	31	1	17	66
4	0	0	5	1	9	15
5	1	1	1	1	7	11
Total	16	38	62	3	47	166

1, no treatment; 2, orthograde treatment; 3, retrograde treatment; 4, root resection; 5, extraction.

radiation dose and better image quality.[23] The results of our study indicate that the use of CT could be considered when planning the retreatment of root-filled maxillary molars. When CBCT is available, it should be preferred over CT. The same recommendation was given by the European Commission for the examination of the temporomandibular joint.[24] In other words, whenever there is an indication for CT, CBCT should be the preferred modality. Mota de Almeida et al[25] found that only 37% of patients who were referred for CBCT by their endodontist would have been referred for CT, if CBCT was not available. They could therefore conclude that CBCT enables more advanced and precise radiological dental examinations for the general population. Hence, our main finding that despite more precise periapical diagnoses, great interobserver decision-making variation prevailed needs to be investigated in similar studies using CBCT rather than CT.

Conclusions

The endodontists in this study exhibited a low degree of agreement when selecting a treatment for root-filled maxillary molars with apical periodontitis.

Adding CT to the intra-oral radiographic examination of the investigated teeth did not result in a significantly higher degree of agreement.

However, the results indicate that CT frequently contributes to a change in the treatment plan.

References

1. Fryback DG, Thornbury JR. The efficacy of diagnostic imaging. *Med Decis Making* 1991; **11**: 88–94. doi: http://dx.doi.org/10.1177/0272989X9101100203
2. Kruse C, Spin-Neto R, Wenzel A, Kirkevang LL. Cone beam computed tomography and periapical lesions: a systematic review analysing studies on diagnostic efficacy by a hierarchical model. *Int Endod J* 2015; **48**: 815–28. doi: http://dx.doi.org/10.1111/iej.12388
3. Rosen E, Taschieri S, Del Fabbro M, Beitlitum I, Tsesis I. The diagnostic efficacy of cone-beam computed tomography in endodontics: a systematic review and analysis by a hierarchical model of efficacy. *J Endod* 2015; **41**: 1008–14. doi: http://dx.doi.org/10.1016/j.joen.2015.02.021
4. Petersson A, Axelsson S, Davidson T, Frisk F, Hakeberg M, Kvist T, et al. Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review. *Int Endod J* 2012; **45**: 783–801. doi: http://dx.doi.org/10.1111/j.1365-2591.2012.02034.x
5. Pak JG, Fayazi S, White SN. Prevalence of periapical radiolucency and root canal treatment: a systematic review of cross-sectional studies. *J Endod* 2012; **38**: 1170–6. doi: http://dx.doi.org/10.1016/j.joen.2012.05.023
6. Kvist T. Endodontic retreatment. Aspects of decision making and clinical outcome. *Swed Dent J Suppl* 2001; **144**: 1–57.
7. Reit C, Gröndahl HG. Endodontic retreatment decision making among a group of general practitioners. *Scand J Dent Res* 1988; **96**: 112–17.
8. Balto HA, Al-Madi EM. A comparison of retreatment decisions among general dental practitioners and endodontists. *J Dent Educ* 2004; **68**: 872–9.
9. Reit C, Gröndahl HG. Application of statistical decision theory to radiographic diagnosis of endodontically treated teeth. *Scand J Dent Res* 1983; **91**: 213–18.
10. Huumonen S, Kvist T, Grondahl K, Molander A. Diagnostic value of computed tomography in re-treatment of root fillings in maxillary molars. *Int Endod J* 2006; **39**: 827–33. doi: http://dx.doi.org/10.1111/j.1365-2591.2006.01157.x
11. Lofthag-Hansen S, Huumonen S, Grondahl K, Grondahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **103**: 114–19. doi: http://dx.doi.org/10.1016/j.tripleo.2006.01.001
12. Cheung GS, Wei WL, McGrath C. Agreement between periapical radiographs and cone-beam computed tomography for assessment of periapical status of root filled molar teeth. *Int Endod J* 2013; **46**: 889–95. doi: http://dx.doi.org/10.1111/iej.12076
13. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; **33**: 159–74. doi: http://dx.doi.org/10.2307/2529310
14. Wittenberg J, Fineberg HV, Black EB, Kirkpatrick RH, Schaffer DL, Ikeda MK, et al. Clinical efficacy of computed body tomography. *AJR Am J Roentgenol* 1978; **131**: 5–14. doi: http://dx.doi.org/10.2214/ajr.131.1.5
15. Hobby JL, Dixon AK, Bearcroft PW, Tom BD, Lomas DJ, Rushton N, et al. MR imaging of the wrist: effect on clinical diagnosis and patient care. *Radiology* 2001; **220**: 589–93. doi: http://dx.doi.org/10.1148/radiol.2203001429
16. Balasundaram A, Shah P, Hoen MM, Wheater MA, Bringas JS, Gartner A, et al. Comparison of cone-beam computed tomography and periapical radiography in predicting treatment decision for periapical lesions: a clinical study. *Int J Dent* 2012; **2012**: 920815. doi: http://dx.doi.org/10.1155/2012/920815
17. Kaeppler G, Cornelius CP, Ehrenfeld M, Mast G. Diagnostic efficacy of cone-beam computed tomography for mandibular fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013; **116**: 98–104. doi: http://dx.doi.org/10.1016/j.oooo.2013.04.004
18. Guyatt GH, Tugwell PX, Feeny DH, Drummond MF, Haynes RB. The role of before-after studies of therapeutic impact in the evaluation of diagnostic technologies. *J Chronic Dis* 1986; **39**: 295–304. doi: http://dx.doi.org/10.1016/0021-9681(86)90051-2
19. Gillan MG, Gilbert FJ, Andrew JE, Grant AM, Wardlaw D, Valentine NW, et al. Influence of imaging on clinical decision making in the treatment of lower back pain. *Radiology* 2001; **220**: 393–9. doi: http://dx.doi.org/10.1148/radiology.220.2.r01au06393
20. Mota de Almeida FJ, Knutsson K, Flygare L. The effect of cone beam CT (CBCT) on therapeutic decision-making in endodontics. *Dentomaxillofac Radiol* 2014; **43**: 20130137. doi: http://dx.doi.org/10.1259/dmfr.20130137
21. Pope O, Sathorn C, Parashos P. A comparative investigation of cone-beam computed tomography and periapical radiography in the diagnosis of a healthy periapex. *J Endod* 2014; **40**: 360–5. doi: http://dx.doi.org/10.1016/j.joen.2013.10.003
22. Ohman A, Kull L, Andersson J, Flygare L. Radiation doses in examination of lower third molars with computed tomography and conventional radiography. *Dentomaxillofac Radiol* 2008; **37**: 445–52. doi: http://dx.doi.org/10.1259/dmfr/86360042
23. Patel S. New dimensions in endodontic imaging: part 2. Cone beam computed tomography. *Int Endod J* 2009; **42**: 463–75. doi: http://dx.doi.org/10.1111/j.1365-2591.2008.01531.x
24. European Commission. *Radiation protection no. 172. Evidence-based guidelines on cone beam CT for dental and maxillofacial radiology*. Luxembourg: Office for Official Publications of the European Communities; 2012.
25. Mota de Almeida FJ, Knutsson K, Flygare L. The impact of cone beam computed tomography on the choice of endodontic diagnosis. *Int Endod J* 2015; **48**: 564–72. doi: http://dx.doi.org/10.1111/iej.12350