

## RESEARCH ARTICLE

# The effect of cone beam CT (CBCT) on therapeutic decision-making in endodontics

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**Objectives:** The aim was to assess to what extent cone beam CT (CBCT) used in accordance with current European Commission guidelines in a normal clinical setting has an impact on therapeutic decisions in a population referred for endodontic problems.

**Methods:** The study includes data of consecutively examined patients collected from October 2011 to December 2012. From 2 different endodontic specialist clinics, 57 patients were referred for a CBCT examination using criteria in accordance with current European guidelines. The CBCT examinations were performed using similar equipment and standardized among clinics. After a thorough clinical examination, but before CBCT, the examiner made a preliminary therapy plan which was recorded. After the CBCT examination, the same examiner made a new therapy plan. Therapy plans both before and after the CBCT examination were plotted for 53 patients and 81 teeth. As four patients had incomplete protocols, they were not included in the final analysis.

**Results:** 4% of the patients referred to endodontic clinics during the study period were examined with CBCT. The most frequent reason for referral to CBCT examination was to differentiate pathology from normal anatomy, this was the case in 24 patients (45% of the cases). The primary outcome was therapy plan changes that could be attributed to CBCT examination. There were changes in 28 patients (53%).

**Conclusions:** CBCT has a significant impact on therapeutic decision efficacy in endodontics when used in concordance with the current European Commission guidelines.

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**Keywords:** cone beam computed tomography; endodontics; decision-making; therapeutics

## Introduction

Diagnosis is indispensable to the understanding of a patient's problem and in setting up a therapy. Imaging is an essential test in endodontics.<sup>1-5</sup> When considering the radiographic method to apply, the aim of maximizing the margin of benefit over harm according to the as low as reasonably achievable (ALARA) principle should be kept in mind. ALARA stands for "as low as reasonably

achievable", which means that one should choose the modality available that offers the lowest radiation dose, whilst at the same time, supplying the information needed.<sup>6</sup> Periapical radiography is the first choice of imaging method in endodontics. It is a test with low sensitivity but high specificity to diagnose periapical periodontitis.<sup>3</sup> Consequently, the test is good at recognizing normalcy and has a low level of false-positive findings, but there is substantial risk for underdiagnosis.

Cone beam CT (CBCT) is a three-dimensional radiographic technique that overcomes some of the drawbacks of conventional periapical radiographs,

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such as geometrical distortion and superimposition of structures.<sup>2,7</sup> CBCT supposedly holds several advantages over plain radiographs when applied in oral diagnosis. It has repeatedly been reported that CBCT reveals more endodontical radiographic findings than do conventional methods.<sup>7-16</sup> The literature, mainly based on *in vitro* studies, supports the hypothesis that CBCT is a method with greater accuracy than periapical radiographs in detecting apical periodontitis, resorptions and root fractures.<sup>17-27</sup>

The effective radiation dose using the state-of-the-art radiologic technique with rectangular collimator and a high-speed film or digital sensor is extremely low.<sup>28</sup> For a CBCT examination to be justified, it needs to be of potential benefit to the patient, *i.e.* it must have the ability to change the treatment decision and patient outcome. Radiation doses from CBCT are generally higher than those for conventional dental radiography.<sup>29</sup> CBCT is also less available and more expensive than conventional methods.

In order to guide clinicians, the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology have released a joint position statement.<sup>5</sup> They recommend that CBCT should generally be limited to the assessment and treatment of complex endodontic conditions. The European Commission has also recently posted evidence-based guidelines for the use of CBCT after carrying out a systematic review of the literature.<sup>29</sup> According to the European Commission guidelines, the best available evidence on CBCT examination for endodontic diagnosis is mainly limited to the two lowest levels of diagnostic imaging as defined by Fryback and Thornbury,<sup>30</sup> *i.e.* technical efficacy and diagnostic accuracy efficacy.<sup>29,30</sup> From the perspective of patients and society, in general, there is a need to ascertain clinical evidence at higher efficacy levels to support current guidelines.

The aim of this study was to determine if the outcome of the CBCT examination, used in accordance with current guidelines, has an impact on therapeutic endodontic decisions in clinical practice.

The secondary aim was to assess whether CBCT examination would improve the subjective precision with which therapy was performed.

## Methods and materials

### Study population

The population was selected from consecutively examined patients recruited from two endodontic specialist clinics in Sweden (situated in Luleå and Uppsala) between October 2011 and December 2012. These are the only reference clinics for endodontics in the respective counties and they treat patients only by referral. Together, the two counties have a population of over half a million people. Three specialists in endodontics and four post-graduate residents took part as examiners in the study. The specialists had, respectively, 11, 31 and 36 years of experience. All the post-graduate residents

were in the second year of their training, and their evaluations were checked by a specialist. The residents had, respectively, 4, 9, 12 and 16 years of clinical experience.

All patients referred to the specialist clinics were examined at the endodontic clinics, extra- and intraorally. The examination was composed of anamnesis, clinical findings such as inspection, probing, palpation and percussion of the area of interest. When appropriate, additional tests such as sensibility tests (cold and electric pulp tests) were carried out. When intraoral radiographs enclosed in the original referral from the general practitioner were deemed to be insufficient, new radiographs were taken at the endodontic clinics using, as far as clinically possible, a parallel technique. All patients had been examined with intraoral radiographs prior to the decision of referring them to a CBCT examination.

In order to assure that every necessary step was included in the examination, a pre-defined form was filled in by the examiner. The pre-defined form *per se* ensured that high quality and, as far as possible, identical clinical examinations were performed by all examiners, allowing a strong basis for forthcoming assessments. After the initial examination, patients judged to be in need of CBCT examination in accordance with the European Commission guidelines<sup>29</sup> were referred to a department of radiology.

### Criteria for cone beam CT examination according to the European Commission guidelines

**Inclusion criteria:** The inclusion criteria for referring patients to CBCT examination were in accordance with current European guidelines and can be grouped as follows:<sup>29</sup>

1. Patients in which disease had to be ruled out:
  - a. patients with symptomatic vital teeth otherwise judged healthy (no exposed dentin; normal sensitivity pulp tests; no tenderness to palpation or percussion; with radiographic apical/marginal periodontal normalcy; and no cracks/fractures)
  - b. patients with symptomatic root-filled teeth otherwise judged healthy (good quality of root filling that did not need to be revised or completed; no tenderness to palpation or percussion; with radiographic apical/marginal periodontal normalcy; and no cracks/fractures)
  - c. when conventional radiology failed to demonstrate if a finding was a pathological process or a normal anatomical structure.
2. Patients in which suspected disease had to be confirmed:
  - a. suspected dental fractures that could not be demonstrated otherwise
  - b. suspected external or internal resorptions.
3. As an aid in performing the therapeutic intervention:
  - a. in established external or internal resorptions to assist in the approach of complex cases

- b. before apical surgery when important anatomical structures interfered with the surgical approach
- c. in diagnosing foreign body structures, their location and, when needed, as a guide in the surgical removal
- d. in understanding tooth anatomy of abnormal teeth in need of endodontic treatment
- e. in assessing the number and location of root canals after at least one unsuccessful attempt to find them under oral microscope.

*Exclusion criteria:* Patients were not referred for CBCT examination if they:

1. presented themselves with an accessible previous volume tomography in the region of interest. This was, however, not a strict restriction if the examiner judged that new and relevant information could be obtained by a new CBCT examination
2. had a definite diagnosis and treatment plan after a complete clinical and conventional radiographic examination and therefore did not need a CBCT examination. This group represented the vast majority of all patients
3. needed any other special imaging technique for soft-tissue assessment such as CT.

#### *Stages of evaluation*

The European Commission guidelines<sup>29</sup> had been implemented in clinics before this study was initiated. They were well established in the local directives for CBCT examination referral.

For calibration purposes, four cases, in which CBCT examination was performed, were discussed with all examiners prior to the study. These cases were not part of the study.

*Stage 1 (before cone beam CT examination):* Before referral for CBCT examination, the examiner wrote down the best available therapy plan, attempting to approach the situation as if a CBCT examination did not exist. A patient could have more than one tooth with a related endodontic problem in need of CBCT examination according to the inclusion criteria. For all such teeth, therapy plans were recorded before the referral for CBCT examination.

*Stage 2 (after cone beam CT examination):* After the CBCT examination was performed, the radiologist wrote a report that was sent to the referring examiner. The examiner then evaluated the images when reading the radiological report. Taking into consideration all data gathered, the previous therapy plan was considered and, if needed, a new therapy plan was created by the same examiner. There was no contact with the patient until the CBCT examination report had arrived and the new therapy plan was decided on by the examiner.

*Stage 3 (patient dismissal):* After performing the therapy and discharging the patient, the same examiner

reviewed the patient's files and filled in a questionnaire about her/his subjective usefulness of the CBCT examination for the therapy plan. The questionnaire is shown in [Figure 1](#). It is a modification of the questionnaire used by Wittenberg *et al.*<sup>31</sup> The examiner also reported changes, if any, between the therapy that was eventually performed and the therapy plan after CBCT examination. Finally, before dismissing the patient, the examiners answered a polar (yes or no) question regarding whether the new information obtained by the CBCT examination had improved the subjective precision of the performed therapy.

The study flow is shown in [Figure 2](#).

#### *Cone beam CT imaging protocols*

The CBCT examinations took place at two separate radiology clinics. The patients referred from the Luleå Endodontic Clinic were examined at the Sunderby County Hospital, Luleå, Sweden, and the patients from Uppsala were referred to the Uppsala University Hospital, Uppsala, Sweden. All CBCT examinations were performed with a 3D Accuitomo 170 (J Morita Manufacturing Corporation, Kyoto, Japan). The radiologists selected a radiographic protocol out of four pre-defined protocols based on the question in the referral. The protocols used were the same at both hospitals. The protocols were the ones used in the ordinary clinical settings. All protocols had the following exposure factors: 85 kV, 5 mA. They differed in rotation (180° and 360°), as well as exposure time (9 s, 17.5 s, 30.8 s). Isotropic voxels with a size of 0.08 mm for 40 × 40 mm and 0.125 mm for 60 × 60 mm volumes were used. Image reconstruction was performed in axial, coronal and sagittal planes. Slice thickness varied between 0.24-, 0.48- and 1.0-mm, with 0.16-, 0.24-, 0.75-mm intervals, respectively.

#### *Data analysis*

Differences in therapy plans between Stages 1 and 2 were plotted in two different graphs. In one graph, the data were presented for all teeth with related endodontic problems in need of a CBCT examination (tooth level),

#### **Choice of therapy**

For this tooth the CBCT exam...

**T1 – led me to choose therapy which in retrospect was not in the patient's best interest**

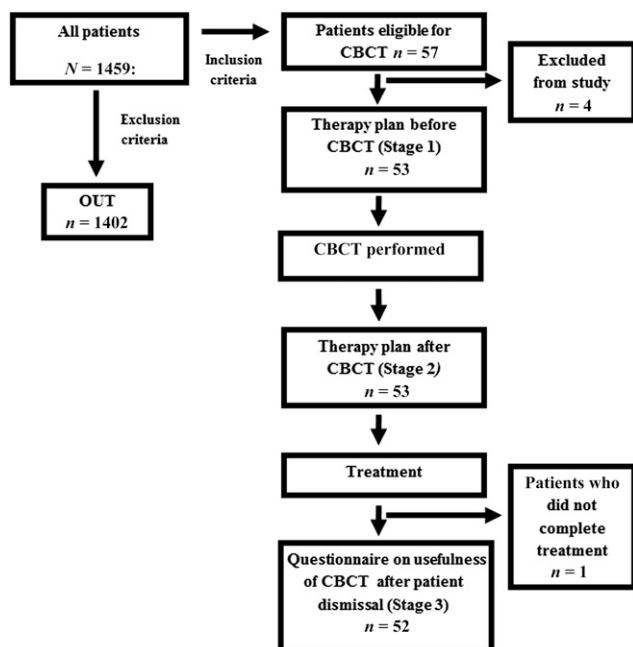
**T2 – was of no influence in my choice of therapy**

**T3 – did not change my choice of therapy but INCREASED CONFIDENCE in the chosen therapy**

**T4 – contributed to a change in the chosen therapy but other factors such as (write down) \_\_\_\_\_ were more important**

**T5 – was very important, compared to other factors in the change of therapy**

**Figure 1** Our questionnaire regarding usefulness of cone beam CT (CBCT) examination adapted from the original questionnaire of Wittenberg *et al.*<sup>31</sup>



**Figure 2** Study flow. CBCT, cone beam CT.

and in the other graph, the data were presented for only the most relevant tooth in each patient (patient level). The most relevant tooth was defined as the tooth in which a therapy plan change was noted. We did not consider changes between a wait-and-watch strategy and no treatment as therapy plan changes.

#### Ethical approval

This study was approved by Umeå's regional ethical board (DNR 2011-443-31M).

## Results

57 patients met the inclusion criteria, representing 4% of the total population of 1459 patients examined at both endodontic clinics during the study period. For each examiner, this proportion varied between 1% and 6%. Of these 57 patients, the examiners failed to report the therapy plan before CBCT in three patients. In another patient, a different CBCT machine was used. Thus, a total of four patients were excluded from further analysis.

There were 53 patients and 81 teeth included in the final analysis. 35 of the patients were females (66%). The mean age was 56.8 years (range, 12–86 years). Only one CBCT volume was performed for each patient. The anatomical distribution of the dental regions examined was as follows: upper posterior region in 29 patients, upper front region in 12 patients, the lower posterior region in 10 patients and the lower inferior region in 2 patients. In four patients, there were teeth examined from adjacent regions; however, they were limited to the same quadrant.

The most common reason for referral for CBCT examination was to differentiate pathology from normal anatomy. The reasons for referral are summarized in Table 1.

The patient's therapy plan changed in 29 patients (55%) between Stage 1 (before CBCT examination) and Stage 2 (after CBCT examination). The changes are presented in Table 2. In two of these patients, the therapy plan for the most relevant tooth in the examination changed from a watchful therapy to surgical intervention, albeit surgery was already planned for other teeth at Stage 1 (before CBCT examination). In another patient (two teeth) a planned surgical intervention was upgraded to be performed by an oral-maxillofacial surgeon because of the expected complexity of the procedure. We have included these in the group in which therapy plan changed.

The changes between Stages 1 and 2 for all teeth are presented in Table 3. In one patient (one tooth), the examiner stated at Stage 2 that the change was not attributed to the information by the CBCT examination but was due to other practical reasons. In 28 patients (53%) and in 35 of all teeth (43%), a modification in therapy plans between Stages 1 and 2 could be attributed to the CBCT examination. A representative case is shown in Figure 3.

52 patients (80 teeth) reached Stage 3 (patient dismissal stage). One patient did not complete the analysis and was excluded from the analysis at this stage. The effect of CBCT examination on patient care as estimated by the examiners is shown in Table 4. The therapy plans conducted after CBCT examinations were executed in all except seven patients. In these seven patients, the post-CBCT therapy plan was modified when therapy was performed. In two of these patients an orthograde treatment was complemented by surgery since the patients' subjective symptoms did not resolve. In one of these last two patients, an orthograde treatment in an unfilled canal was performed after CBCT. In another patient, planned surgery was postponed as the patient's subjective symptoms resolved. Two patients refused recommended treatment, which was orthograde conventional treatment. One of these wanted his tooth extracted. One patient in whom extraction was advised after CBCT underwent explorative surgery, as she wanted to do everything to save the tooth. Surgery confirmed that the tooth was unsalvageable owing to a fracture, and it was eventually extracted. In the last patient, a possible lesion of the pulp horn underneath a tooth filling was revealed to be an artefact upon removal of the filling.

The examiners judged that the CBCT examination helped to improve the subjective precision of the performed therapy in 26 patients (50%).

## Discussion

#### Methodological considerations

Assessing the efficacy of diagnostic imaging is a concern of the radiologic community and has evolved along

**Table 1** Reasons for referral to cone beam CT examination

Reasons for cone beam CT examination referral	Patient's main problematic tooth, n <sup>p</sup> (%)	All examined teeth with endodontic problems, n <sup>t</sup> (%)
R1	4 (8)	12 (15)
R2	6 (11)	6 (7)
R3	3 (6)	3 (4)
R4	25 (47)	39 (48)
R5	13 (25)	19 (23)
R6	2 (4)	2 (2)
Total	53 (100)	81 (100)

n<sup>p</sup>, number of patients; n<sup>t</sup>, number of examined teeth; R1, symptomatic teeth judged healthy; R2, suspected dental fractures; R3, suspected or established resorptions; R4, differentiating pathology from normal anatomy; R5, pre-surgical aid; R6, location of foreign body structures.

a path similar to that of medical decision-making. The various approaches to assessing the efficacy along this path can be placed in a framework of medical decision-making as a conceptual model for efficacy assessment. Fryback and Thornbury<sup>30</sup> have developed a six-stage hierarchical evaluative framework to assess the efficacy of imaging methods. Every imaging method has different grades of efficacy. A schematic picture of the framework is shown in Figure 4.

In most diagnostic methods, and also in CBCT examinations, the current available data from the literature are mainly limited to the first two levels: technical efficacy and the diagnostic accuracy efficacy (Levels 1 and 2).<sup>29</sup> Furthermore, these data are based principally on *in vitro* studies. Therefore, we still do not know how information influences the clinician's chain of thoughts, *i.e.* how CBCT examinations influence diagnoses and therapy plans. We lack knowledge about the impact of CBCT examinations on patient outcome.

This study was designed as a prospective observational study in which the patient acted as a control to

**Table 2** Therapy plans before and after cone beam CT (CBCT) examination for the patient's main problematic tooth

Therapy plan before CBCT examination (n <sup>p</sup> )	Therapy plan after CBCT examination (n <sup>p</sup> )								Total (n <sup>p</sup> )
	A	B	C	D	E	F	G	H	
A	1	–	1	3	–	–	–	–	5
B	2	2	3	3	–	–	3	1	14
C	2	–	6	1	–	1	2	–	12
D	–	–	3	9	–	2	1	–	15
E	–	–	–	–	1	2	–	–	3
F	–	–	–	–	–	3	–	–	3
G	–	–	–	–	–	–	–	–	0
H	–	–	–	–	–	–	1	–	1
Total (n <sup>p</sup> )	5	2	13	16	1	8	7	1	53

A, no treatment; B, watchful waiting; C, orthograde endodontics; D, retrograde endodontics; E, explorative surgery; F, extraction; G, referral to other specialist; H, other; n<sup>p</sup>, number of patients. Grey boxes represent no changes. We have not considered it as a change when switching between a “wait and watch” plan and “no therapy”.

The number of patients who had a therapy change after CBCT examination are represented in white background.

**Table 3** Therapy plans before and after cone beam CT (CBCT) examination for all examined teeth with endodontic related problems

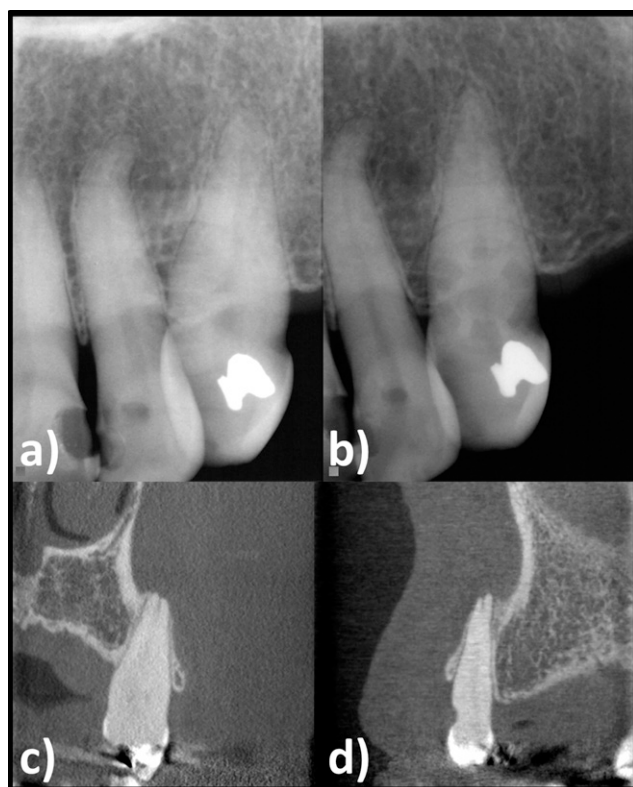
Therapy plan before CBCT examination (n <sup>t</sup> )	Therapy plan after CBCT examination (n <sup>t</sup> )								Total (n <sup>t</sup> )
	A	B	C	D	E	F	G	H	
A	7	1	2	3	–	–	–	–	13
B	5	4	3	3	–	–	5	1	21
C	2	–	8	1	–	1	3	–	15
D	–	–	3	15	–	2	2	–	22
E	2	–	–	–	1	2	–	–	5
F	–	–	–	–	–	4	–	–	4
G	–	–	–	–	–	–	–	–	0
H	–	–	–	–	–	–	1	–	1
Total (n <sup>t</sup> )	16	5	16	22	1	9	11	1	81

A, no treatment; B, watchful waiting; C, orthograde endodontics; D, retrograde endodontics; E, explorative surgery; F, extraction; G, referral to other specialist; H, other; n<sup>t</sup>, number of examined teeth. Grey boxes represent no changes. We have not considered it as a change when switching between a “wait and watch” plan and “no therapy”.

The number of teeth that had a therapy change after CBCT examination is represented with a white background.

him/herself. It aimed to examine whether the use of CBCT examinations in selected endodontic cases results in a shift of therapy plans. This approach represents the fourth level, *i.e.* therapeutic decision efficacy, in Fryback and Thornbury's<sup>30</sup> hierarchical model. Other studies<sup>31–34</sup> have used quite similar designs to assess diagnostic thinking efficacy (Level 3) and therapeutic efficacy (Level 4) of other imaging methods in diverse fields. These kinds of studies have inherent limitations. Guyatt *et al*<sup>35</sup> highlighted the following limitations: stated “before” plans might differ if technology was actually not available, and physicians' subconscious bias might affect the results. These limitations are difficult, if not impossible, to overcome. Patient outcome assessment is another limitation as there are no controls for the implemented therapy. However, it was outside the scope of this study to evaluate patient outcome. The present study has two main strengths; its well-defined consecutive population and the fact that the CBCT examination was requested only after a thorough clinical examination. Our study design also allowed current clinical practice and care to be observed without interference, which has bestowed the study with a high degree of external validity.<sup>36</sup> The results have high applicability to clinical practice, although generalization should be made with some caution, as differences in socioeconomics, demographics and justice might have an impact. The study design with actual real clinical therapy planning as outcome measure renders blinding not only impossible but also unethical.

Another method used to measure therapeutic efficacy is randomized controlled trials (RCTs). Although RCTs are highly ranked and are able to measure patient benefit, they also have some limitations. The patients who potentially could benefit the most from an imaging method sometimes have to be excluded for ethical reasons. The definition of the problem needs to be restricted, and blinding of the caregiver is impossible.<sup>37</sup>



**Figure 3** 57-year-old female who had complained of apical tenderness of tooth 23 for several years. Intraoral radiographs (sensitivity of 0.55 and specificity of 0.98 for apical periodontitis<sup>3</sup>) did not reveal apical pathology, and cold and electrical pulp tests were indecisive. Tentative planning before cone beam CT examination was 6-month follow-up. 1.5 months later cone beam CT examination (higher sensitivity and specificity than intraoral radiographs for apical periodontitis<sup>3</sup>) revealed the apex of tooth 23 fenestrating the buccal cortical plate, and a rounding of the tooth apex confirming the clinical suspicion of apical periodontitis. Orthograde endodontic treatment revealed a necrotic pulp, and symptoms were relieved after treatment. (a) Mesial eccentric and (b) orthogonal intraoral radiographs; (c) coronal plane and (d) sagittal plane cone beam CT examination of tooth 23.

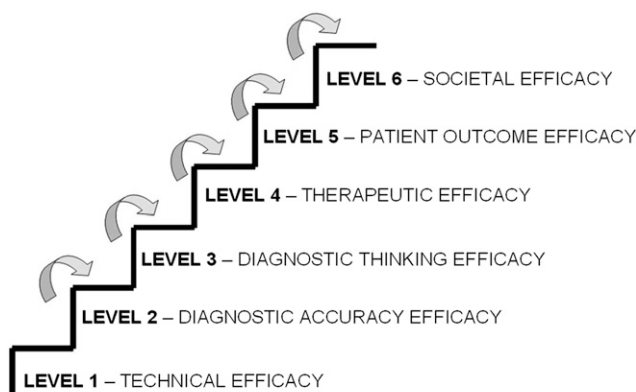
### Consideration of the results

The results showed that CBCT examination when used in accordance with the European Commission guidelines<sup>29</sup> is a powerful tool with significant potential to modify

**Table 4** Estimated usefulness of cone beam CT examination according to Wittenberg *et al*<sup>31</sup>

Usefulness of cone beam CT	Patient's main problematic tooth, n <sup>p</sup> (%)	All examined teeth with related endodontic problem, n <sup>t</sup> (%)
T1	1 (2)	1 (1)
T2	5 (10)	8 (10)
T3	20 (38)	39 (49)
T4	9 (17)	11 (14)
T5	17 (33)	21 (26)
Total	52 (100)	80 (100)

n<sup>p</sup>, number of patients; n<sup>t</sup>, number of examined teeth; T1, was not in the patient's best interest; T2, had no influence in therapy; T3, did not change therapy but increased confidence; T4, contributed to a change in the selected therapy; T5, was the most important factor in the therapy change.



**Figure 4** Fryback and Thornbury's<sup>30</sup> framework of the efficacy of diagnostic imaging.

the decisions made by the clinician in endodontic cases. It could be argued that the examiners were open to subjective swings owing to the problem with blinding. The outcome measure was the actual therapy that the examiners performed. Almost all of the cases were discussed with other colleagues in therapy meetings. The changes in therapy were, however, nearly always based on changes in diagnoses. This is reported in another paper (Mota de Almeida FJ *et al*, Tandvårdens Kompetenscentrum, Sweden, personal communication). These facts challenge the hypothesis that the reported therapy changes were due to subjective swings. The low variation in referral rates between different examiners indicates a good agreement on how to interpret and execute the guidelines. There is always a risk that the examiners have refrained from referring patients who could be included according to the guidelines creating a positive bias in the results outcome. We judged this risk to be limited as all CBCT examinations were performed within the national health care insurance limits and did not infer extra costs either to the referring clinics or patient.

The most dramatic impact that a diagnostic method could have on therapeutic decision efficacy is a change in therapy plans.<sup>30</sup> In one study,<sup>31</sup> it has been reported that cranial CT changed therapy in 19% of the patients, and in another study, CT helped to change to a beneficial therapy plan in approximately 15% of the patients.<sup>31,33</sup> Higher frequencies were shown for MRI in joint diseases but were still <50%.<sup>32,34</sup> The major factor behind the high therapeutic decision efficacy outcome in our study was probably the strict selection criteria achieved by stringent adherence to the European Commission guidelines.<sup>29</sup> The 57 patients represent 4% of all examined patients during the study period. For the vast majority of the patients, normal clinical and radiographic examinations were considered to be sufficient in order to establish a good diagnosis and therapy plan. Presumably, a CBCT examination would not be beneficial to those patients and would thus expose them to deleterious radiation without gain. Balasundaram *et al*<sup>38</sup> compared CBCT examination with intraoral radiographs and found that for easily diagnosed endodontic cases, CBCT examination does not provide

information that can change a therapy plan. However, in their study, the clinical findings and anamnesis were not taken into consideration.

It was outside the scope of this study to evaluate patient outcome. Yet, the examiners felt retrospectively that CBCT examinations helped them to change to a better therapy in a large number of patients when answering the questionnaire in Stage 3 (patient dismissal). As RCT studies are very difficult to perform, these data will probably be the closest information possible at the patient outcome efficacy level in endodontics.

Our results could partly be explained by the researchers' unconscious bias to demonstrate the effectiveness of the CBCT examination.<sup>35</sup> We have tried to overcome this bias firstly by instructing and repeatedly reminding all participating dentists to be as neutral as possible in all assessments. Secondly, we highlighted the necessity of imaging a pre-CBCT examination era whilst diagnosing and setting the therapy before the CBCT examination. In other words, what would they have done if they did not have access to CBCT examinations and had to take action?

The therapeutic decision efficacy at the tooth-unit level was not as high as at the patient level. This is probably explained by the fact that the dentists sometimes decided to include neighbouring teeth in the evaluation, despite a high degree of certainty of the diagnosis and therapy plan in these teeth. The rationale behind this was probably that these teeth would still be included in the field of view for CBCT examination. Had these teeth been the only teeth to be examined, the patient would only have had a small benefit from the CBCT examination. A similar trend could be seen amongst the examiners who participated in the study. As the frequency of CBCT referrals increased, possibly due to the less strict criteria, the impact of CBCT examination in therapeutic decision-making decreased. This highlights the necessity of strict criteria when exposing patients to radiation, following the ALARA principle.<sup>6</sup> It should be emphasized that, according to the current European Commission guidelines,<sup>29</sup> CBCT examinations are not intended to screen patients and should be used in only complex cases.

Another factor contributing to the high number of shifts in therapy plans could be that the clinicians had a precautionous attitude before the CBCT examination.

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The non-treatment and watch-and-wait strategies accounted for approximately 40% of patients and all teeth before CBCT examinations, but this dropped to approximately 10% of patients and 25% of all teeth after CBCT examinations. In the era before CBCT was introduced, time was on the side of the dentist and watchful waiting was a powerful diagnostic and therapeutic tool. The introduction of CBCT examination might result in a shift towards a more active therapy that hopefully helps the patient sooner. Whether or not such a development is in the best interest of the patient this study cannot say for certain; however, for CBCT examinations to improve patient outcome, it first has to be demonstrated that they can provoke a change in diagnosis and therapy. The results of this study indicate that the CBCT technique has that ability when used properly.

## Conclusions

Volume tomography with CBCT, when used in accordance with the current European Commission guidelines:<sup>29</sup>

- is recommended for only a small group of patients with complex endodontic problems
- has a significant impact on therapeutic decision efficacy in endodontic cases
- helps to improve the subjective precision of the performed therapy.

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