

# Case Selection for the Use of Cone Beam Computed Tomography in Dentistry Based on Diagnostic Efficacy and Risk Assessment

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## Abstract

Case selection for cone beam computed tomography (CBCT) for dental purposes is primarily based on individual risk-benefit assessment, balancing between the long-term radiation risks of CBCT and its ultimate benefit for each individual patient. Based on the currently available literature, the expected ultimate benefit to the patient, as evaluated by the level of diagnostic efficacy of CBCT in dentistry, is yet unclear, and it is mainly limited to its technical and the diagnostic accuracy efficacies. Even for these levels of efficacy, evidence is incomplete. Therefore, the efficacy of CBCT in supporting the practitioner's decision making, the treatment planning, and eventually in affecting treatment outcomes is not fully elucidated. On the other hand, the potential radiation risks of CBCT scan are uncertain and are stochastic in nature, thus requiring a preventive clinical approach. Consequently, cautious decision making is warranted when a CBCT scan is considered. This chapter reviews the current literature concerning the benefits of CBCT in dental practice, alongside its risks in this use, and presents a practical case-selection algorithm for the use of CBCT in dentistry.

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## 7.1 Introduction

Cone beam computed tomography (CBCT) was introduced in the late 1990s to construct three-dimensional scans of the maxillofacial region at a reduced radiation dose compared to the conventional CT [1–11] and has become a popular diagnostic technique in dentistry [1, 2, 12]. Although

the effective radiation dose of CBCT scans is indeed reduced compared to multi-slice computed tomography (MSCT), it is still significantly higher than intraoral radiography or panoramic radiography [12, 13]. In addition, the long-term health risks of CBCT use in dentistry are unclear [2, 14–18]. It is therefore an acceptable practice that every effort should be made to reduce the overall effective radiation dose to the dental patient [2, 4, 12].

In recent years there has been a debate whether CBCT should be used as a standard preoperative imaging modality in dentistry [5–11, 19–23]. For example, it was stated in the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) joint position statements from 2010 [2] and from 2015 [1] that CBCT should not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms [1, 2]. However, the exact criteria for using CBCT for endodontic purposes are not sufficiently clear [2, 24–27], and the latest published data demonstrate that CBCT is being used also for routine endodontic purposes, such as preoperative evaluation of root canal system anatomy [28, 29], determination of root canal working length [30–33], identification of a healthy periapical tissue, or diagnosing vital teeth with irreversible pulpitis [12, 34, 35]. The increased usage rates of CBCT in dental practices, along with its unknown long-term health risks, present a significant long-term health concern [2, 4, 12, 36–38].

The decision to perform a CBCT scan must be justified on an individual basis by demonstrating that the benefits to the patient outweigh the potential radiation exposure risks [1, 2, 39]. Therefore, the case selection of CBCT is primarily a question of risk-benefit assessment [2, 12, 39]. These potential benefits to the patient should be largely based on the efficacy of the CBCT as a diagnostic imaging modality for each specific dental evaluation [2, 12, 39–41].

Diagnostic efficacy may be defined as “the probability of benefit to individuals from a system or test under ideal conditions of use” [12, 42]. A shallow view of the efficacy of diagnostic

imaging would be that it should provide images of sufficient quality for diagnostic purposes that it was intended for [40, 41]. However, a more comprehensive point of view is required in order to evaluate the ultimate benefit of an imaging modality to an efficient and effective treatment of a patient [40, 41].

This comprehensive point of view on the efficacy of an imaging modality involves parameters that are beyond the technical characteristics and the accuracy of the imaging modality [12, 41, 42]. It should include also additional higher levels of efficacy evaluation such as the efficacy of this modality to support the practitioner’s decision making and treatment planning and eventually to improve the treatment outcome [12, 41, 43].

This chapter reviews the current literature concerning the benefits of CBCT in dental practice, alongside its risks in this use, and presents a case-selection algorithm for the use of CBCT in dentistry.

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## 7.2 The Potential Benefits

It has been stated that CBCT should be considered for diagnosis only if a review of the patient’s health and imaging history together with a meticulous clinical examination lead to a conclusion that CBCT may significantly contribute to achieve an accurate and consistent diagnosis [2, 19, 39, 44, 45]. However, the need to achieve an accurate diagnosis is not the only factor that should be considered for adequate case selection – it is prudent that the decision to use CBCT be justified by demonstrating that the ultimate benefits to that particular patient outweigh the potential risks of radiation exposure [2, 12, 39].

The expected ultimate benefits of CBCT to the patient may be evaluated by levels of diagnostic efficacy. The diagnostic efficacy hierarchical model presented by Fryback and Thornbury [41] is a comprehensive tool for appraisal of the literature on efficacy of a diagnostic imaging modality [12]. It is comprised of six levels of imaging efficacy that include not only the technical characteristics of the imaging modality but also the

efficacy of this modality to support the practitioner's decision making and treatment planning and to eventually improve treatment outcome [12, 41, 43].

This model [40, 41] includes the following efficacy levels (in a hierarchical order, from the lowest to the highest efficacy level):

The *technical efficacy* – the technical quality of the images

The *diagnostic accuracy efficacy* – the diagnostic accuracy associated with interpretation of the images

The *diagnostic thinking efficacy* – the effect of the obtained radiographic information on clinician's estimate of the probability that a patient suffers from a disease or health condition

The *therapeutic efficacy* – the effects of the radiographic information on the patient's management plan

The *patient outcome efficacy* – the effect of the obtained radiographic information on patient's outcomes

The *societal efficacy* – the impact of the imaging modality on society as a whole [12]

This model is aimed to draw conclusions regarding the diagnostic efficacy of any imaging modality based on the currently available literature, and it has been used in recent years in dental research to evaluate the diagnostic efficacies of CBCT [12, 20, 21, 23, 40].

Numerous studies have been published on the applications of CBCT in dentistry, and the significant variability in their study designs generated inconsistent and confusing results [4–11, 13, 24, 25, 27–35, 45–47]. Evidence-based dentistry (EBD) is an approach to oral healthcare that integrates the best available clinical evidence to support a practitioner's clinical expertise for each patient's treatment needs and preferences [48–50]. Therefore, systematic reviews, which constitute the foundations of EBD, are of utmost importance in the evaluation of the diagnostic efficacy of CBCT in dentistry [48, 50, 51].

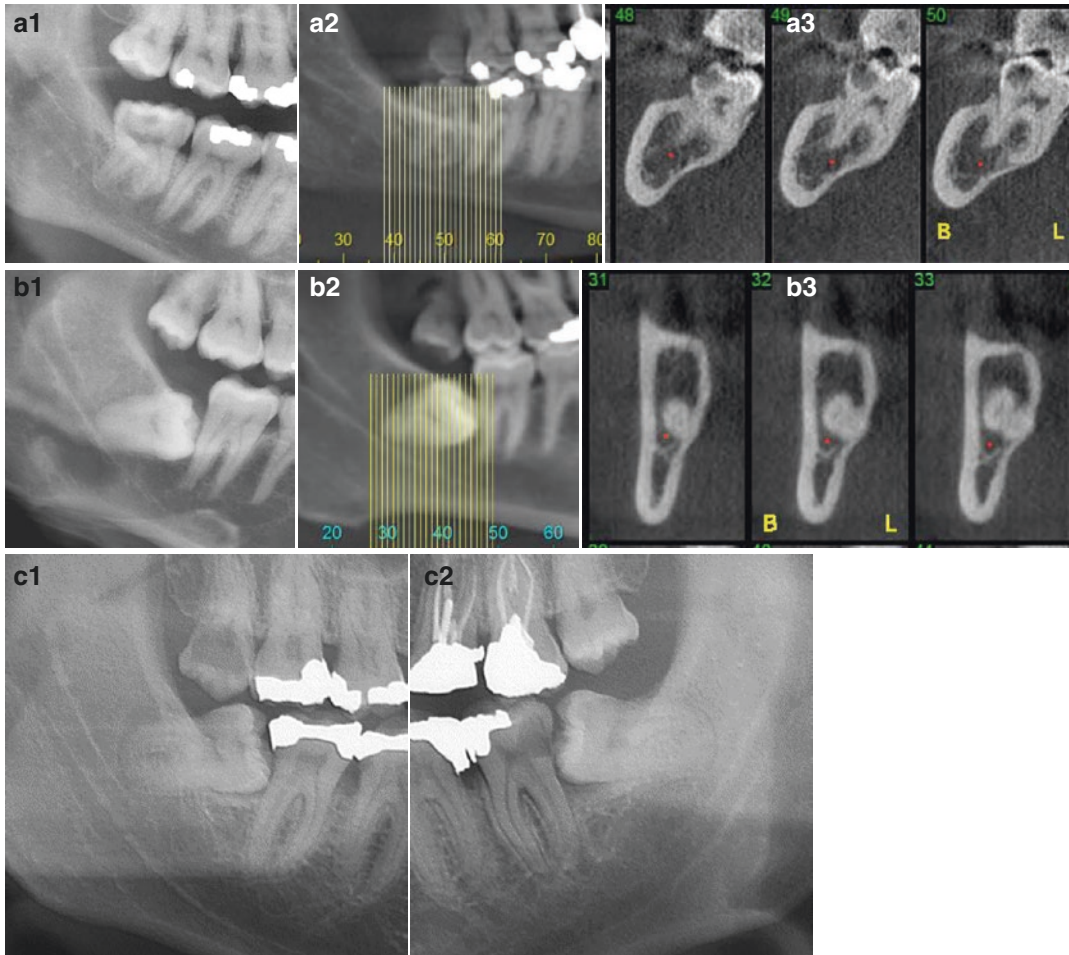
A recent systematic review [20] evaluated the evidence for the diagnostic efficacy of 3-D cep-

halometry in orthodontics and concluded that the current evidence for it is limited. In this systematic review, only six studies met the criteria for a moderate level of evidence, stressing the need for methodologically standardized studies on a 3-D cephalometric analysis [20].

Another study [21] evaluated the available clinical research and diagnostic efficacy studies in the oral and maxillofacial radiology literature and concluded that the current literature consists mostly of case reports, case series, and cross-sectional studies, assessing mostly technical efficacy and diagnostic accuracy [21]. In this review the authors stated that “such studies do not provide strong evidence for clinical decision making nor do they address the impact of diagnostic imaging on patient care” and that “more studies at the higher end of the study design and efficacy hierarchies are needed in order to make wise choices regarding clinical decisions and resource allocations” [21].

Another recently published study [43] evaluated the efficacy of CBCT for assessment of mandibular third molars using the hierarchical model by Fryback and Thornbury [41] and reported that only few high-evidence studies on the efficacy of CBCT for radiographic examination of mandibular third molars currently exist [43]. They stated that “periapical or panoramic examination is sufficient in most cases before removal of mandibular third molars. However, CBCT may be suggested when one or more signs for a close contact between the tooth and the canal are present in the two-dimensional image – if it is believed that CBCT will change the treatment or the treatment outcome for the patient” [43] (Fig. 7.1).

In a recent study [12], a systematic review of the literature was performed to identify and analyze studies evaluating the use of CBCT in endodontics. Initially 485 possible relevant articles were identified. However, following the application of strict inclusion criteria, only 58 articles (12%) met the inclusion criteria and were analyzed and allocated to levels of efficacy according to the Fryback and Thornbury model [41]. Most eligible articles ( $n=52$ , 90%) evaluated technical characteristics or the accuracy of



**Fig. 7.1** (a–c) Presents three cases of assessment of mandibular third molars that are planned to be extracted. (a) The right mandibular third molar was scheduled for extraction. The initial panoramic radiograph (*a1*) was not sufficient in order to plan the procedure, and therefore CBCT evaluation was performed (*a2*, *a3*). (b) The right mandibular third molar was scheduled for extraction. The initial

panoramic radiograph (*b1*) was not sufficient in order to plan the procedure, and therefore CBCT evaluation was performed (*b2*, *b3*). (c) The *left* (*c2*) and the *right* (*c1*) mandibular third molars were scheduled for extraction. The panoramic radiograph was sufficient in order to plan the procedures. Therefore, CBCT was not performed

CBCT, defined in this model as low levels of efficacy [41]. Only six articles (10%) proclaimed to evaluate the efficacy of CBCT to support the practitioner's decision making and treatment planning and ultimately to affect the treatment outcome, defined as higher levels of efficacy. They concluded that the expected ultimate benefit of CBCT to the endodontic patient as evaluated by its level of diagnostic efficacy is yet unclear and is mainly limited to its technical and

diagnostic accuracy efficacies. They therefore concluded that a cautious and rational approach is advised when considering CBCT for endodontic purposes [12] (Fig. 7.2).

A comprehensive systematic review of the entire dental literature [40] assessed the risks and benefits of CBCT in dentistry. In that systematic review, it was reported that the understanding of CBCT's diagnostic efficacy in dentistry was largely limited to the first two lower levels of





**Fig. 7.2** Case selection of CBCT for the diagnosis and treatment of teeth with complex anatomy: two comparable cases of an additional third root in mandibular molar teeth scheduled for root canal treatment are presented. In case #1 CBCT was indicated, and in case #2 CBCT was not indicated. **Case #1a–1g** A lower second mandibular molar with an additional third root was scheduled for endodontic treatment. However, preoperative (**1a**) and intraoperative (**1b**) periapical Rx's, together with a thorough inspection by surgical operation microscope during the treatment did not provide sufficient information to locate

the additional root. The patient was referred to CBCT that confirmed the presence and location of the additional third root (**1c–1e**). This root was endodontically treated (**1f, 1g**). **Case #2a–2c** A lower first mandibular molar with an additional third root was scheduled for endodontic treatment. Preoperative (**2a**) and intraoperative (**2b**) periapical Rx's, together with a thorough inspection by surgical operation microscope during the treatment provided sufficient information to locate and endodontically treat the additional root (**2c**). Therefore, in this case CBCT was not indicated

efficacy (i.e., the technical and diagnostic accuracy efficacies) and that even for these, knowledge is incomplete. In this review only a few publications were identified which addressed

higher levels of diagnostic efficacy [40, 41]. The authors concluded [40] that “development of guidelines with high evidence grades was precluded” and that it also “highlights the need for

clinical trials which will provide information on higher level efficacies, notably patient outcome efficacy”[40].

It is therefore evident that the current dental literature assessing the efficacy of CBCT as a diagnostic imaging modality is limited to the lower levels of efficacy, specifically to the technical characteristics, or to the accuracy of the imaging modality [40, 41]. These low levels of efficacy may be a prime interest for some clinicians; however, they provide only a partial view of the potential ultimate benefit of CBCT to patients [12, 40, 41]. Since the ultimate goal of medical diagnosis is to treat patients effectively and efficiently, only higher levels of diagnostic efficacies (e.g., therapeutic efficacy, patient outcome efficacy, and societal efficacy, defined as levels 4–6 of efficacies) are capable to provide a comprehensive view of the ultimate benefit of the modality to patients or to the society as a whole [12, 40, 41].

In this context, a high-quality imaging modality such as CBCT may be ineffective in certain instances, while an imaging modality of a lesser quality such as intraoral radiography may be of significant value in certain instances [12, 40, 41]. In addition, in order for an imaging modality to be considered efficacious at a higher level in this hierarchical model of diagnostic efficacy (e.g., therapeutic efficacy and patient outcome efficacy), it must be efficacious at lower levels, but not the other way around. In addition, improvements in the efficacy at a lower level (e.g., technical efficacy) will not guarantee an ensuing improvement at the higher efficacy levels (e.g., patient outcome efficacy) [12, 41, 42].

This asymmetry is often not well understood in dental research reports dealing with diagnostic efficacy levels 1 and 2 (e.g., technical efficacy) [40, 41], in which an improvement in some technical characteristics of CBCT or in its accuracy in a certain clinical scenario may incorrectly lead to a conclusion that these new findings also guarantee an improvement in higher levels of efficacy (e.g., the patient outcome) and in the expected ultimate benefit to the patient. It also highlights the need for additional clinical trials which will provide information on higher level efficacies, especially regarding patient outcome efficacy [12, 40].

Adequate professional standards for performing CBCT imaging in a certain patient should be based on selection criteria derived from the best available evidence [22]. However, the current available dental literature provides a very limited view on the ultimate benefit of CBCT to patients. In conclusion, as recently stated: “in this expanding era of CBCT imaging in dentistry, the apparent urgency of adopting glittering new technology should be balanced with diligent discovery and patience”[22].

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### 7.3 The Potential Risks

In general, CBCT produces a higher radiation dose than traditional intraoral radiography, but less than that produced during a multi-detector CT scan [39]. However, the comparison of radiation doses by itself is too simplistic, as aside from the physical properties of the CBCT machine, estimation of radiation health effects requires an understanding of the nature of the X-ray radiation and its tissue effects and should also take into consideration a variety of other parameters such as the scanning parameters, the patient demographics, and the nature of the exposed tissues and organs [12, 13].

Diagnostic X-ray is an electromagnetic (EM) ionizing radiation with a small wavelength, deep penetration, and high energy transfer capabilities [4, 13, 39, 40, 52] that potentially may cause tissue damage and specifically DNA damage leading to chromosomal mutations and ensuing formation of malignancy [40]. These ionizing effects have no threshold radiation dose and are considered as “chance” (“stochastic”) effects, making the distinction between “harmless” and “dangerous” exposures to radiation impractical [4, 13, 39, 40, 52]. Thus, any exposure to X-rays should not be considered as risk-free [4, 12, 13, 39, 40, 52].

The effective dose of CBCT scans, which takes into consideration also the specific radiosensitivity of the evaluated tissues [40], varies among scanners and depends on both clinical parameters such as the region of the jaw being scanned and on acquisition parameters, such as

the field-of-view (FOV) dimensions, exposure time, and the tube electric current and potential [13]. A recent meta-analysis of the literature [53] analyzed the reported effective dose estimations of dental CBCT examinations and found large variations: the reported adult-effective doses ranged from 46 to 1073  $\mu\text{Sv}$  for large FOVs, between 9 and 560  $\mu\text{Sv}$  for medium FOVs, and between 5 and 652  $\mu\text{Sv}$  for small FOVs. The reported child-effective doses ranged from 13 to 769  $\mu\text{Sv}$  for large or medium FOVs and from 7 to 521  $\mu\text{Sv}$  for small FOVs. They concluded that “large exposure ranges make CBCT doses difficult to generalize” [53].

In addition, the radiation damage experienced by an exposed group and its descendants is gender and age dependent [36–38, 40]. At all ages, the reported risks for females are slightly higher than for males [13]. It has been reported that the risk is tripled in children under 10 years old in relation to the risk at age 30 [40]. Children’s cancer risk per unit dose of ionizing radiation is higher than adults, and they have a longer lifetime risk of developing radiation-induced cancers [2, 17, 39]. Therefore, additional strict considerations should be weighted prior to the exposure of children to CBCT scanning [36–38].

Radiation risk management is the assessment of future-associated health risks, including the effect of uncertainty, followed by efforts to minimize the probability and impact of these suspected adverse effects [36–38, 54]. CBCT radiation risk management requires a combination of two principles: *justification*, defined as “doing more good than harm to the patient,” and *optimization* based on the “ALARA” principle – as low as reasonably achievable, meaning to obtain the necessary diagnostic information using the lowest radiation dose that can be reasonably achieved [40]. However, the uncertain long-term and stochastic nature of radiation risks requires a preventive clinical approach [2, 13, 39, 54], which may not always be easy to implement [12, 36–38].

The traditional nonpreventive approach to health hazards, *late lessons from early warnings* [55], is described as delayed learning from his-

torical early worrying events [55]. A historical medical example of this approach is the story of asbestos: in 1898, Lucy Deane, a United Kingdom (UK) industrial inspector, observed and reported about *the evil effects of asbestos dust* [55]. However, only in 1998 the UK government, followed by the European Union (EU), decided to ban the use of asbestos [55], and current future estimates suggest that the number of asbestos-related fatalities in Western Europe would reach about a quarter of a million over the next 35 years [56]. This devastating outcome is an example to a misuse of the concept of precaution when dealing with a potential health hazard and to the need to adopt a modern preventive approach [55].

In this context, preventing long-term health hazards sometimes requires acting before there is an established proof of harm [55]. The *precautionary principle* represents a modern preventive approach to health hazards that can be defined as a “better safe than sorry approach suggesting that action should be taken to avoid harm even when it is not certain to occur” [57]. However, this preventive approach may be especially difficult to implement when the impacts of the potential health hazard are far into the future and the immediate perceived benefits from avoiding current preventive measures are significant [12, 55–58].

In the context of CBCT imaging, the potential immediate benefit to the individual patient from the use of CBCT imaging in dental practice may be perceived as substantial [2, 12, 59]. However, the relatively high radiation doses associated with CBCT compared to conventional radiography [13] still raise long-term health concerns especially regarding a potential increase in the risk of malignancy and especially in children [2, 14–18, 26, 36–38, 60]. Furthermore, the adverse effects of the CBCT radiation exposure may not be seen until years after the actual exposure [2, 13–18, 36–38]. Thus, implementing the precautionary principle in the decision making when considering a CBCT scan for dental purposes is prudent [2, 12, 55, 57].

With the growing popularity of CBCT technologies among dental practitioners [2, 13], concerns have also been expressed about the level of

training, education, and experience required to interpret the CBCT data [39]. In addition to CBCT data on the region of interest, CBCT scans usually include additional adjacent anatomical structures that are usually not visible in the FOV of routine intraoral radiographs, and the practitioner who performs a CBCT study is obligated to systematically examine the entire CBCT image data and report on any anatomical abnormalities or pathological conditions observed [2, 39, 40, 61]. However, this diagnostic obligation requires a comprehensive radiology knowledge of head and neck anatomy and pathology that may be beyond the dental practitioner qualifications, thus subjecting the patient to risks of undiagnosed or misdiagnosed pathological conditions and the practitioner to an ensuing medicolegal liability risk [54, 61].

#### 7.4 Case Selection Algorithm for the Use of CBCT in Dental Practice: Benefit Versus Risk

The potential benefits to the patient as judged by the imaging diagnostic efficacy of CBCT should be weighed against the potential radiation risks to that particular patient by applying the precautionary principle to eliminate the uncertainty regarding the long-term health concerns of the radiation exposure. This process must be evidence based [12, 48, 51, 54]. Dental practitioners must stay scientifically updated with the ongoing research and development of the CBCT technology, and with the associated potential long-term radiation risks [14–17, 36–38, 40, 55, 60], and apply an evidence-based approach in case selection for performing CBCT [12, 39, 49].

When the decision whether to use CBCT is not based on solid systematic evidence-based foundations, it may lead to misuse or overuse of CBCT, exposing the patient to unnecessary radiation risks without any clinical justification [13, 39]. As an example, it became acceptable and common to use CBCT for the diagnosis of vertical root fractures (VRF), a complex endodontic condition [62], assuming that CBCT is clinically effective for this purpose and that it possesses

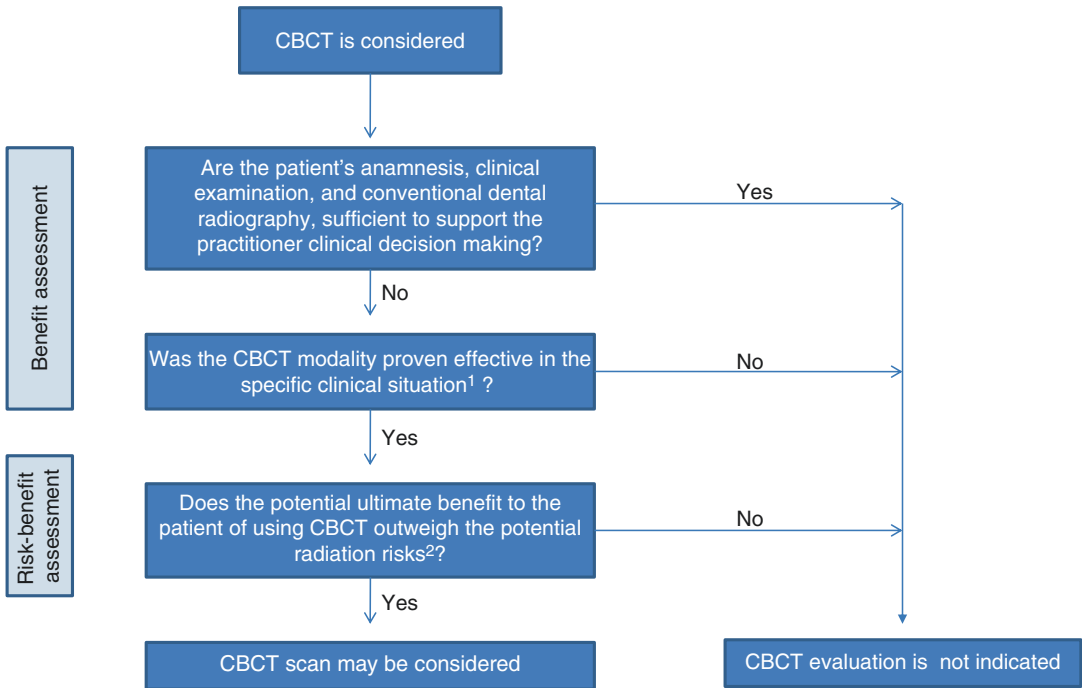
superior efficacy over conventional radiography [26, 46, 63–76]. Nevertheless, recent published data, including a recent meta-analysis of the literature [25], raises a concern regarding the alleged superiority of CBCT over conventional intraoral radiography for the detection of VRF [24, 25, 27], especially in the presence of metal posts [27]. The exact extent of CBCT scans performed for the diagnosis of VRF is unknown, but is clearly extensive [26]. However, the limited evidence raises a significant concern regarding its clinical effectiveness for the diagnosis of VRFs [12, 13, 24, 25, 27, 39], regarding its superiority over alternative lower-dose conventional dental radiography modalities [13, 24, 25, 27, 39], and regarding its potential ultimate benefit to the patient compared to its potential radiation risks [2, 14–18, 26, 60].

A number of position statements [1, 2, 39] suggested several clinical scenarios when CBCT may be indicated. However, according to the currently available scientific literature on the diagnostic efficacy of CBCT in dentistry, these recommendations are not well supported by a high level of efficacy evaluation [40]. In addition, the caution that is required due to the associated radiation risks of CBCT is commonly presented without a thorough explanation and without adequate implementation of the precautionary principle in light of the uncertainty regarding its possible unknown long-term health risks [12]. Therefore, it is recommended that the selection of patients to be referred to CBCT should be based on an assessment of the need for additional imaging, the benefit of CBCT in that clinical scenario, and the risks of performing CBCT to that particular patient as follows:

*Need Assessment:* Assessment whether the patient's anamnesis, clinical examination, and lower-dose conventional dental radiography are sufficient or not for the specific diagnostic process

*Benefit Assessment:* Assessment whether the diagnostic efficacy of CBCT is scientifically established, not only for the technical characteristics of the CBCT but also for the efficacy of CBCT to improve the practitioner's decision





**Fig. 7.3** Case selection algorithm for CBCT scan in dentistry.<sup>1</sup>The diagnostic efficacy of CBCT for the specific clinical situation is scientifically supported not only for the technical characteristics of the CBCT but also for the efficacy of CBCT to support the practitioner’s decision making, the

treatment planning, and ultimately the treatment outcome, in that particular clinical scenario.<sup>2</sup> The potential radiation risks to the particular patient should be assessed by applying the precautionary principle, considering the uncertainty regarding the long-term health concerns of exposure to radiation

making and treatment planning and ultimately the treatment outcomes

*Benefit Versus Risk Assessment:* Assessment whether the potential ultimate benefit to the patient of using CBCT outweighs the potential radiation risks to the particular patient, assessed with the precautionary principle regarding the long-term health concerns of exposure to radiation

technical and the diagnostic accuracy efficacies. Even for these levels of efficacy, evidence is incomplete. On the other hand, the potential radiation risks of CBCT scan are uncertain and stochastic in nature, thus requiring the implementation of the precautionary principle by a preventive clinical approach. Based on these principles, a practical algorithm for the use of CBCT in dentistry is proposed (Fig. 7.3).

The application of these criteria in the case selection for CBCT will ensure the efficient and cautious use of CBCT in dentistry (Fig. 7.3).

**Conclusions**

The selection of cases requiring CBCT in dentistry is primarily based on a risk-benefit assessment. The expected ultimate benefit to the patient, as evaluated by the level of diagnostic efficacy of CBCT in dentistry, is not fully elucidated, and it is mainly limited to its

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