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# Evidence-Based Indications of Cone Beam Computed Tomography in Children with maxillary impacted canines - A literary review

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## Abstract

**Objectives:** This literary review aimed to see what research and evidence there is for CBCT imaging of impacted maxillary canines in children and young adults.

**Methods:** A search  for literature was conducted in Oria and PubMed, and some articles were manually collected. All articles had to comply with an inclusion and exclusion criteria. The articles were examined and the results used to discuss the topic.

**Results:** 23 articles were screened through abstracts and titles to merit further scrutiny. After reading the remaining 23 articles, 12 were chosen to be eligible and the remaining 11 were excluded. Meaningfull results from the articles were extracted and used for discussion.

**Conclusion:**  CBCT imaging of impacted canines in children is, in most cases, unnecessary to reach a treatment plan and, therefore, should not be used as a screening method. There are however, clinical cases that merit CBCT imaging and give patients better treatment and seemingly a shorter treatment time.

The following Indications for CBCT of impacted canines have been proposed: suspicion of root resorption, insufficient information from conventional 2D radiographic imaging, imaging prior to surgical exposure in difficult cases as determined by the acting physician, or angulation of canines above 30 degrees with unclear pulpal involvement of lateral and central incisors.

# Introduction

Impacted canines occur in about 1-3% of children, with a slightly higher occurrence in female patients (1). Tooth impaction is defined as failure of a tooth to erupt at its appropriate position in the dental arch or within its normal time of eruption (2). Maxillary canines are the second most impacted tooth after the third molars (1, 3, 4).
The reasons for impacted canines can be many, such as mesiodens, supernumerary teeth, and impacted primary teeth amongst other conditions. In many cases, intraoral radiographs give the clinician adequate diagnostic information to treat patients with impacted canines. Still, in some cases, additional examinations have to be considered, and chief among these are Cone Beam Computed Tomography (CBCT) examinations.

Image provided by the radiological department at UiB.

Panoramic imaging or orthopantomography (OPG) have a long history of being used in the treatment of impacted canines along with intraoral imaging using the Parallax technique or Clarks technique (5). In many cases, these traditional imaging techniques are adequate for the diagnosis and decision-making of treatment plans for patients. However, these images do have limitations when it comes to diagnostics with respect to the canine position and possible root resorption in the adjacent teeth in some cases. There are also known projection-related distortions and uncertainties that come with 2D imaging, such as OPG, that may lead to further diagnostic imaging being needed. Examples of this would be uncertainty when it comes to root resorption and its severity, the exact location of the canines, and suspicion of ankylosis (6). All these factors are needed to be clarified by the clinician before treating children with impacted or supernumerary teeth (7).

Imaging of impacted canines is the most common request for CBCT imaging of children and young adults (2). Since the demand for this modality is seemingly only going to increase, the evidenced-based indications for CBCT examinations in children need to be investigated and guaranteed to provide improved treatment to patients compared to conventional 2-dimensional radiological examinations. Indications for CBCT imaging of children will always need to be under greater scrutiny since children are more susceptible to the effects of radiation than adults (8). This literary review seeks to look at evidence-based indications for CBCT examinations of children with impacted maxillary canines. Special considerations are put on the diagnostic benefit and radiation risk assessment to justify the increased effective dose to the patient.

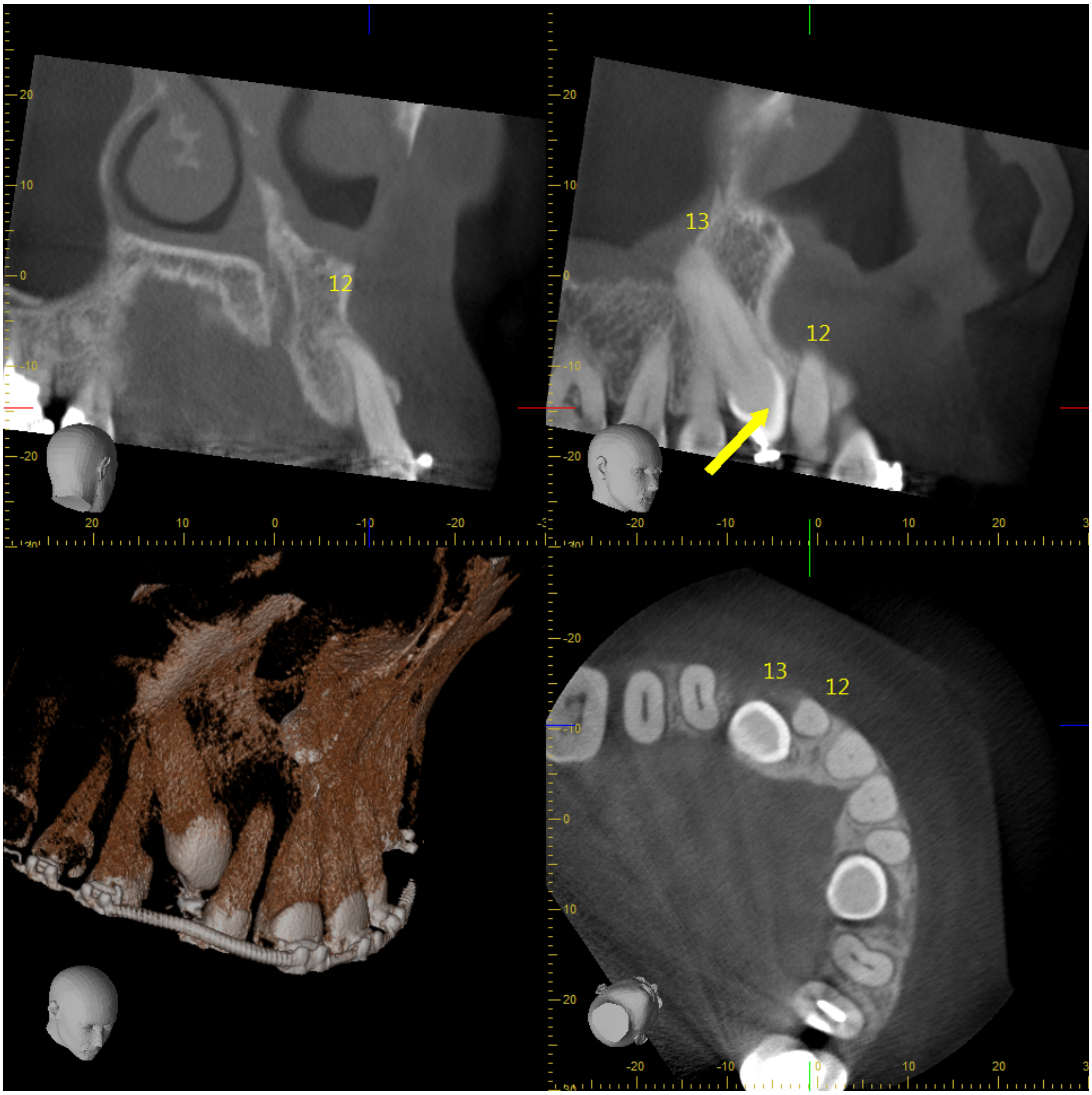


Image provided på the radiological department at UiB.

CBCT imaging gives invaluable 3-dimensional diagnostic information with a superior spatial resolution for many dental and orthodontic procedures to aid diagnosis and treatment plans (1). The access, clinical use, and need for CBCT imaging have increased dramatically in recent years (7, 9).

The pressures of treating children and the knowledge of potential long-term and life-changing consequences make the need for clinical certainty and choice of the least invasive treatment crucial. With these high demands also come greater requirements for pre-treatment planning. A significant part of this planning is radiological examinations of the highest diagnostic quality, which puts CBCT at the top of the list when 3-dimensional diagnostic information is required to provide certainty in diagnostics and pre-treatment planning.

## CBCT exposure parameters, effects of radiation, and regulating and governing bodies

### Cone Beam Computed Tomography

Sanjay et al. state that CBCT is the most significant advance in digital imaging in dentistry since the panoramic radiograph (10). CBCT is a volumetric imaging modality that gives superior hard tissue depiction in the maxillofacial region. It does in fact, offer a higher spatial resolution of bone structures in the cranial and facial region than CT imaging and offers a lower dose to patients than CT imaging. The dose given by a CBCT image ranges between 11 – 1087 μSv (9). The images are obtained by a divergent (cone-shaped) source of ionising radiation, and the attenuated photons this generates are detected by a detector that rotates parallel to the radiation source. With 50 different maxillofacial CBCT machines available on the market currently, there is a whole host of different terms and apparatus for clinicians to learn and understand. The difference between CBCT and other radiographic imaging in dentistry is that CBCT images collect volumetric data which enables a reconstruction of the digital information. The digital information is calculated by algorithms and reconstructed into a 3D image that the clinician can manipulate. The use and application of these images has been expanded to surgical planning, construction of surgical guides and production of bio-models as well as more traditional use in diagnostics and spatial awareness before clinical procedures.

### Technical parameters affecting dose

CBCT examinations give a higher radiation dose to the patient than other dental x-ray procedures and should, therefore, only be considered when diagnostic quality has not been

obtained by previous lower-dose examinations (10). The reason for this is that a CBCT takes multiple images that are rendered together to enable a 3D image to be produced.
When a CBCT examination has been indicated, all parameters and procedures should be assessed and optimised to ensure the lowest possible radiation exposure to the patient and the highest image quality. These criteria include *justification*, optimisation of *radiation parameters* and *lead shielding* (9).

The quality and quantity of the photon beam are adjusted by manipulating mAs and kVp. The quantity of photons in an X-ray beam is adjusted by increasing or decreasing the mAs. This regulates the number of electrons fired at the radiation source to produce photons for imaging. The kVp, the tube voltage, regulates the quality of the photons. Increasing the kVp will increase the photons' penetrative power and the number of photons within the optimal wavelength. An increase in kVp will also mean an increase in the quantity of an X-ray beam which is a factor that must also be considered when planning a procedure (10).

Tube filtration is done by materials such as aluminium or copper to absorb low energy photons that will not aid in image capture and instead be absorbed by the patient increasing the radiation dose to the patient (DOP).

The "Field off view" (FOV) or scan volume limits the radiation exposure to the "Region of interest" (ROI) and thereby limits radiation to the patient. Limiting the radiation to the ROI also leads to less scattered radiation, which decreases image quality. The FOV should always be tailored to the individual patient.

Figure 1 demonstrates an overview of radiation doses received from the various dental examinations and the equivalent dose from other daily activities or medical examinations. Curtesy of White et al. (10).

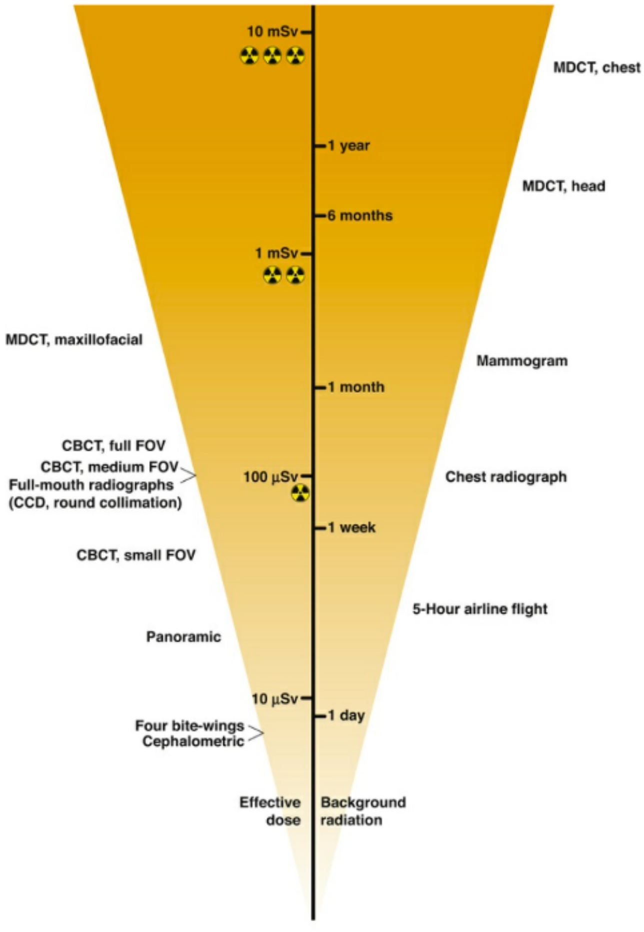


**Fig 1**

## Cellular damage by radiation

X-rays are a form of electromagnetic radiation (EM). These can be described as photons or packets of energy that have the potential to ionise atoms. This energy electrons surrounding the atom absorb and are relocated to a shell further from the atom's nucleus. The medical implications of ionising radiation are that human cells can suffer damage from this exposure. The damage we consider most harmful is the damage done to DNA strands through such exposure (11).

In most cases of diagnostic radiation, this damage is reversible, and the cells can repair the damage. Still, in some cases, it may be permanent, leading to a mutation that can lead to a tumour being formed. This process takes time, but the stochastic risks are always there. No form of radiation is without risk, whether high or low-dose examinations (12). The risk of tumours forming can be calculated, and it is essential to calculate and optimise, when possible, the exposure given to the public, staff, and patients. Limited research suggests that exposure can lead to an increased risk of brain, salivary gland, and thyroid tumours after exposure to x-rays through dental examinations (12).

## Current industry standards for radiation justification

With the increased demand for ionising imaging, the need for optimal image quality at the same time as the ALARA principles (As Low as Reasonably Achievable) are upheld is essential for the safe use of the modality.

When it comes to radiation exposure in children, the criteria must be stricter given the known stochastic effects of ionising radiation and the faster cell proliferation among children and young adults. The harmful effects to exposed tissue have longer to manifest in young adults, given their longer life expectancy and have a greater chance of mutating and becoming cancerous (8).

The international Commission on Radiological Protection (ICRP) has some defined goals for treating patients and using radiographic imaging. Their aim is to prevent the unnecessary use of radiographic imaging, and in cases where ionising radiation is needed to treat patients, its ionising effects should be made to be as low as possible. The three target areas to achieve this are *justification (indications evaluated on an individual level)*, *optimisation of protection*, *and individual effective and equivalent dose limits*. Given the stochastic effects that ionising radiation is known to give, this should be a priority amongst those who use the modalities to treat patients (13). Children are at an even greater risk than the general population, given that we know of previously mentioned stochastic effects and that these effects from radiation exposure typically show after 20-45 years. The faster cell division in children also means that the potential for cellular mutations in children is greater than in adults (8).

Chart showing average contribution of organ doses to effective dose for CBCT in adults (9).

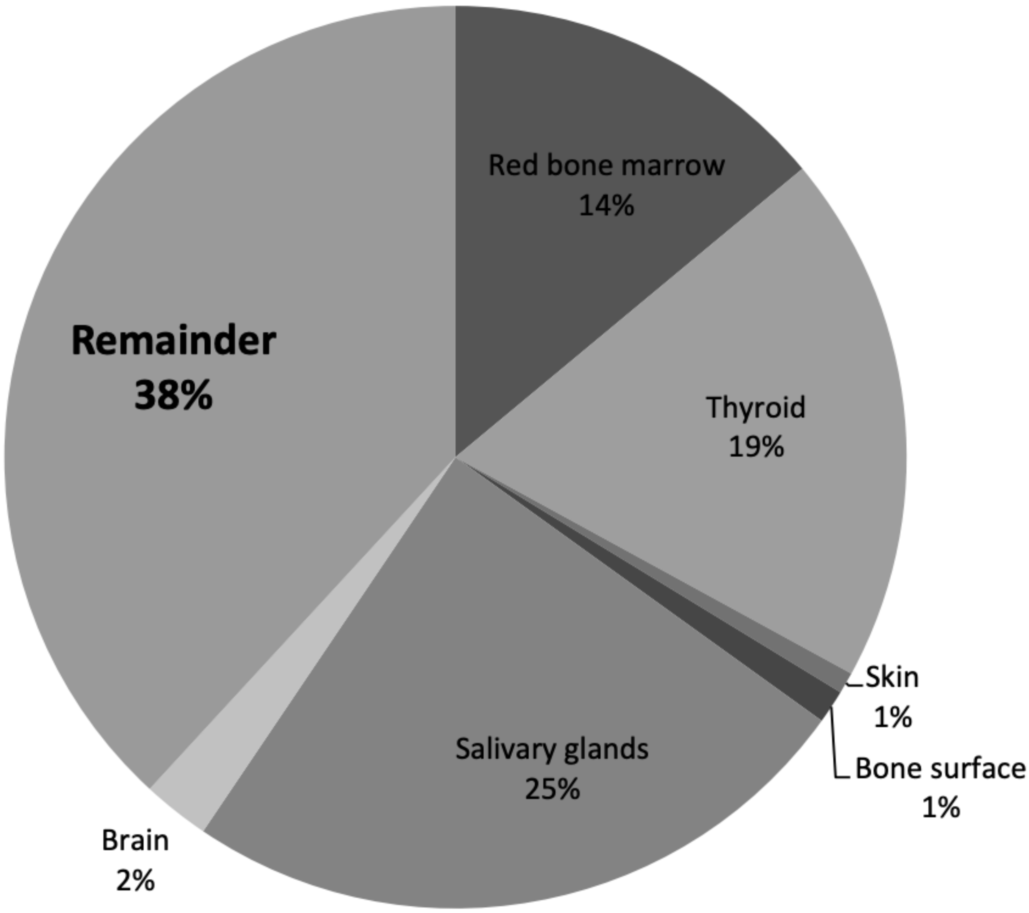


Fig 2

Dose measurement

Dose measurement and calculations are commonly made through the use of phantom heads or other body parts/limbs and the attachment of dosemeters that register the given dose. Many such tests are done by manufacturers and researchers in the field of dose optimisation and image quality. When it comes to measurements in children, child-equivalent phantoms must be used, and the difference in cell proliferation and tissue must be taken into account. As previously mentioned, the dose range for a CBCT examination is typically between 11-674 µSv for a localised CBCT examination and between 30-1087 for an examination in craniofacial region. (9)

Effective dose from conventional dental imaging techniques in µSv. MSCT= multislice CT (9).

| | |
|---|---|
| Intraoral radiograph | <1.5 µSv |
| Panoramic radiograph | 2.7 – 24.3 µSv |
| Cephalometric radiograph | <6 µSv |
| MSCT maxillo-mandibular | 280 - 1410 µSv |
| CBCT, dento-alveolar | 11-674 µSv |
| CBCT, craniofacial | 30-1087 µSv |

Fig 3

## International regulation

Regulation and guidelines for the use of radiation in medical imaging are regulated worldwide. In Europe the governing bodies are organisations such as the ICRP and the SEDENTEXT project commissioned by the European Commission. Guidelines for the use of CBCT and CT are made to ensure the safety of staff, the public and the patient (12, 14).

## SEDENTEXCT guidelines for patient selection criteria

SEDENTEXCT lay down guidelines that use "referral criteria" or "selection criteria" in determining which patients need CBCT imaging before treatment. The criteria er defined by a patient's clinical signs, dental history, and clinical symptoms (9). All examinations should be justified and lead to a net gain for that patient, not be attainable with other lower dose alternatives. Routine use of CBCT is prohibited and unacceptable in the treatment of patients (15).

### Aims

This paper aims to review articles and literature that carry out prospective clinical trials and retrospective investigations to determine the benefits of CBCT imaging of children with impacted maxillary canines. Through a revision of the material, gaining a greater impression of what evidence there is for CBCT imaging of children with impacted canines.

## Method

To identify relevant literature on this topic, a search was done in the search engine Oria belonging to University of Bergen (UiB) and in PubMed given access through the University of Bergen. This gave access to all available literature and articles the author could obtain. Eligibility criteria were determined before the search, and abstracts and titles of the articles were read to see if they met the inclusion criteria. These criteria are discussed below. If included, the full-length articles were retrieved and read in their entirety. Screening of titles and abstracts, choice of articles considering the determined eligibility criteria and quality considerations were made by the author and mentor. PRISMA-guide to writing was used to gain a structure to the article.

### Ethics

As this is a review of available literature on the topic of CBCT indications in children, no applications were needed from the ethics board to obtain the information required.

### Choice of database

Upon starting this article, the choice was made to search in the search engines Oria and PubMed. This would give the author hits on all searches that were available to him. PubMed was added to ensure that algorithm patterns in Oria did not exclude literature from the search and to include one of the most important search engines in the medical literature.

## Search Strategy

A PICO survey was used to find an adequate search for the literary review (table 1). This was done to help target the areas of interest and to help draft synonyms to help find articles on the chosen topic.

Further, a MeSH search was also performed to help include indexed words in published articles to aid in narrowing the search results to relevant articles. The MeSh search is included in the table below. One key search phrase was used for each search engine.

PICO survey to help concentrate the search and consider strategy.

| | | | |
|---|---|---|---|
| P | Population/problem | Orthodontics, impacted canines, impacted maxillary canines | |
| I | Intervention | CBCT, Cone Beam Computed Tomography, Cone Beam CT | |
| C | Comparator | Treatment, Benefits, planning | |
| O | Outcome | Indications, requisitions | |

Table 1

## Literary search

The following search strategy was implemented to gather articles (09.11.22):

- *PubMed:* "Tooth, Impacted"[Mesh] AND Cone beam CT AND Children
- *Oria:* Cone Beam CT Children impacted canines/Cone Beam CT AND children AND "impacted canines."

All searches were done with the publication dates limited to 2013 – 2022. In Oria searches were restricted to all English articles, and had to concern dentistry, oral surgery, or orthodontics. The number of articles and inclusion or exclusion are listed in the PRISMA flow chart illustrated in the results.

## Eligibility criteria

When going through articles and literature on this topic, some criteria were determined to be considered and included.

- When viewing articles, no publications before 2013 are to be included. The reason for this is a desire to find studies that hold themselves to the updated guidelines for radiation protection in paediatric radiology implemented in 2013 (ref, ICRP).
- Regarding the publication languages, the search has been restricted to English publications. This will ensure publications with similar guidelines from regulators to the Norwegian guidelines and provide articles that are discernible to the author.
- Cases were required to have a CBCT examination due to impacted maxillary canines.
- Patients were not to have craniofacial syndromes, odontomas, cysts, trauma, or cleft lip/palate.
- The author evaluated the abstracts before inclusion in the study. Eligible studies include indications and clinical trials for CBCT examinations of impacted canines.

### Quality assessment

The chosen articles and studies were assessed by the author. Titles and abstracts were the bases for further reading and inclusion or exclusion.

### External articles included

Some external articles were included in this study. These were articles found through the reference list from articles included in the initial search or manually searched.. These articles were included because of the greater depth they give and some for the factual and technical information they provide to the paper.

## Results

### Study selection

Table 2 illustrates the PRISMA *Flow diagram* summarising the search results and the selection process used to include or exclude articles. It shows the number of articles found, the number of articles screened and included, and the number of articles read in full.

After reading through the abstracts or main titles, one hundred articles from the initial search did not meet the inclusion criteria and thus were excluded. Of the 123 articles found after the initial search, 23 were screened through abstracts and titles to merit further scrutiny. After reading the remaining 23 articles, 12 were chosen to be eligible and the remaining 11 were excluded.

Other relevant articles have been included that were not obtained from the initial search. These articles have been found through references from the article selection and recommendations from my mentor. To be included, the articles still had to meet the same inclusion criteria as for the initial search.

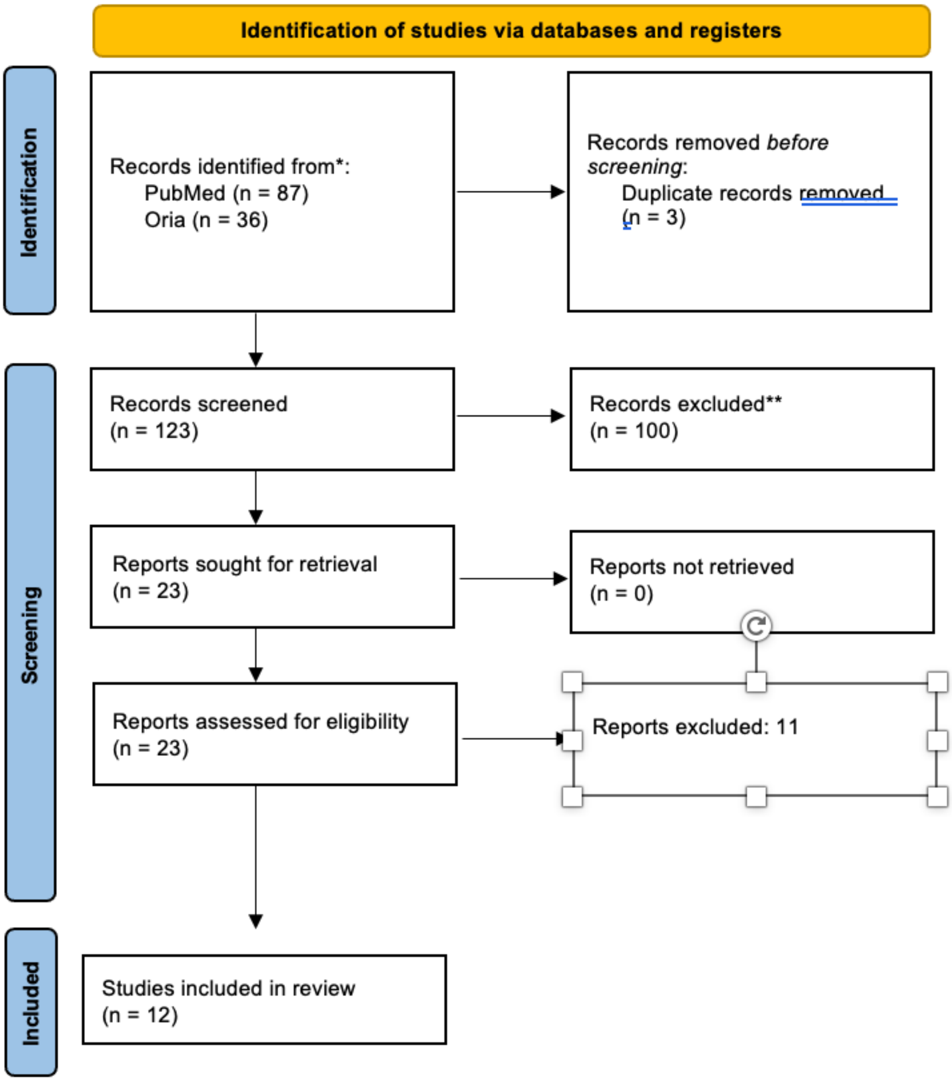
Identification of studies via databases and registers
Identification
Records identified from*:
PubMed (n = 87)
Oria (n = 36)
Records removed before screening:
Duplicate records removed
(n = 3)
Screening
Records screened
(n = 123)
Records excluded**
(n = 100)
Reports sought for retrieval
(n = 23)
Reports not retrieved
(n = 0)
Reports assessed for eligibility
(n = 23)
Reports excluded: 11
Included
Studies included in review
(n = 12)

*Table 2*

## Description of included articles design and summary

| Authors and Paper TItle | Study Design<br>Number of patients<br>Number of evaluators | Major findings |
|---|---|---|
| *“Pittayapat P. et al. "Agreement between cone beam computed tomography images and panoramic radiographs for initial orthodontic evaluations”* Sosars P. et al.*tion"* | Retrospective<br>38<br>8 | CBCT images yielded greater agreement between the two groups of practicing orthodontists and radiologists. |
| "*Comparative analysis of panoramic radiography and cone-beam computed tomography in treatment planning of palatally displaced canines*" | Retrospective<br>88<br>Unknown | Panoramic images were only able to show severe root resorption, and the authors found that the use of CBCT is indicated in cases of impacted maxillary canines where there is a suspicion of root resorption on neighbouring teeth. |
| *“Radiographic features in 2D-imaging as predictors for justified CBCT examinations of canine-induced root resorptions”* Andersen A.K.H. et al. | Retrospective observational<br>99<br>2 | Panoramic imaging is inadequate for detecting canine-induced root resorption. |
| *"Impacted upper canines: examination and treatment proposal based on 3D versus 2D diagnosis".* Wriedt et al. | Diagnostic cross-over study<br>21<br>26 | 82% of treatment suggestions were the same regardless whether there was a 3D image or not. |
| Alqerban A et al.*"The effect of using CBCT in the diagnosis of canine impaction and its impact on the orthodontic treatment outcome".* | Retrospective<br>118<br>Uknown | Treatment time was significantly shorter (4 months) for the group with a CBCT compared to the group with only a panoramic image. |
| Oenning A.C. et al.*"Cone-beam CT in paediatric dentistry: DIMITRA project position statement".* | Guideline | This paper aims to give guidelines for indication for the use of CBCT imaging in paediatric patients. |
| Christell H. et al *"The impact of Cone Beam CT on financial costs and orthdontists' treatment decisision in the management of maxillary canines with eruption disturbance"* | Web-based Survey<br>12 cases<br>112 | Most treatment decisions were the same regardless if a CBCT image was available or not. |

| | | |
|---|---|---|
| Alqerban A. et al.*"Orthodontic treatment planning for impacted maxillary canines using conventional records versus 3D CBCT"* | Retrospective/ prospective?<br>40<br>4 | There was no significant difference in treatment planning between cases that made use of CBCT and those that relided only on normal 2D imaging. |
| Alqerban A et al. *Pre-Surgical treatment planning of maxillary canine impaction using panoramic vs cone beam CT imaging".* | Prospective study<br>32<br>6 | Not found to be a significant difference in pre-surgical planning based on whether a CBCT image was available or not. There was an increase in confidence in the CBCT based treatment plans compared to the 2D image treatment plans. |
| *Botticelli S."Two- versus three-dimensional imaging in subjects with unerupted maxillary canines".* | Single-blind study<br>27<br>8 | The findings demonstrated a difference in accuracy of findings and higher confidence in CBCT images. |
| Apostolos I.T et al.*"Reliability of different radiographic methods for localisation of displaced maxillary canines".* | 20<br>3 | In the conventional images different diagnoses were consistently given from all tree examiners. There was no disagreement between examiners when viewing the CBCT images. |
| Bjørksved et al.*"Are panoramic radiographs good enough to render correct angle and sector position in palatally displaced canines?"* | Prospective<br>58<br>Uknown | Results show that panoramic images had systemically higher values than in the CBCT images. The conclusion was that panoramic imaging gives an overestimate of PDC sector and angle to midline position compared with the CBCT images, but clinically the differences are quite modest. |
| Ilhis R. et al. *Cone beam computed tomography indications for interdisciplinary therapy planning of impacted canines».* | Retrospective<br>89<br>5 | If preliminary diagnosis based on 2D radiographs is not conclusive for determining possible root resorption and if extraction of permanent tooth/teeth is considered in the therapy plan, a CBCT is indicated.<br>CBCT is indicated when the impacted canine has a horizontal position. |

| | | |
|---|---|---|
| «Pediatric Phantom Dosimetry of Kodak 9000 Cone-beam Computed Tomography». | | |
| Haney E. et al. «Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines». | Prospective<br>18<br>7 | Results showed that 2D and 3D images produced different diagnoses for impacted canines and treatment plans. |

## Discussion

The evidence for CBCT imaging of children with impacted third canines is varied, and each case needs to be considered and follow the ALARA and ALADA principles individually. The results from the articles found for this paper show varied impact CBCT imaging has on treatment plans.

When a patient has impacted canines, the clinician must start by giving a diagnosis and then conceiving a treatment plan for the patient. One article found that patients who had a CBCT done prior to treatment for impacted maxillary canines were finished on average 4 months earlier with their treatment than the control group who only had a panoramic image (16). Alqerban A. et al does state, however, that more research is needed for this to be applicable to all treatment cases. Impaction per se is not justified for CBCT examination; the diagnostic benefit must overcome the potential radiation risk, especially for younger patients. The same author found in another study that CBCT imaging did not significantly affect treatment time (11). This is conflicting, but it can point to the fact that CBCT, with its increased accuracy, can lead to certain patients being treated more efficiently with less uncertainty during treatment.

## CBCT reliability and diagnostic confidence (agreement between and within observers)

Another finding of this review is that when practitioner groups only consider panoramic images, there is more uncertainty among clinicians and specialists (5, 17). CBCT imaging on the other hand has a much higher consensus between parcticioners when they consider anatomy and pathology. This  higher consensus could lead to a patients treatment plan being less prone to changes in cases were there is uncertainty after the initial panoramic image findings (17).  The argument can be made that an increase in a clinician's certainty before further treatment procedures is in the patient's and clinician's best interest. Panoramic and conventional 2D images do also entail a certain amount of subjective opinion when it comes to image interpretation (5). This might support Alqerban A. et al. and the reduced treatment time found for patients with CBCT imaging (16). It was also found that confidence was low among orthodontists after only 2D imaging before treatment planning (11).

Though many different CBCT machines are available on the market, the core principles for image acquisition remain the same across different machine brands. A basic understanding of image acquisition will allow staff to manipulate and utilise dose-reduction strategies (10). This must be implemented in all cases where 3D imaging is thought to benefit patients treatment.

When considering the biological effects of radiation exposure and the need for clinical accuracy it is in the patients best interest for CBCT imaging in cases with deep impacted, or horizontal displaced canines (18). With the need for surgical exposure of the tooth, there seems to be more emphasis on the clinicians' treatment planning and surgical strategy (11). Justification does however always need to be done for each patient when considering the need for CBCT regarding the localization, possible root resorption, and extraction strategy. In these cases with uncertainty the DIMITRA project guidelines conluded that these are justified indications for CBCT imaging of children and young adults (7).

## CBCT diagnostic accuracy: 3D vs 2D

The limitations of panoramic and other 2D imaging techniques have been discussed in many articles compared to that of CBCT. The possible image distortion and superimposed 3D anatomic structures make these images more demanding for accurate interpretation.

This being said, there are many advantages with Panoramic and other 2D imaging. They give lower radiation doses, are widely available, and in most cases give acceptable diagnostic information for the treatment planning of patients. Therefore, when introducing a new imaging technique with higher radiation in dental clinics, the diagnostic impact needs to be investigated and compared to conventional methods.

This leads to the fact that many cases are found to be unaffected by the information gained from CBCT imaging and treatment planning remains unaltered (11).

Some articles note that the choice for CBCT imaging of impacted canines takes place for difficult clinical cases (16). From a radiation protection point of view, CBCT should not be used as a screening method in children with impacted maxillary canines. It is therefore important to find a consensus that maximises both diagnostics and radiation protection to the public. This needs to be taken into consideration when looking and reviewing the need for CBCT imaging as routine. It is also a common consensus that CBCT imaging should not be made as standard for the treatment of impacted canines in children and young adults (11, 15). It does however not take away from the fact that CBCT is the preferred examination in these difficult cases that require more planning and detailed analyses. Alqerban A. et al. also found that orthodontist were in agreement of which difficult level a treatment was after CBCT imaging where they had previously been uncertain after traditional 2D examinations (11).

The referral reasons for CBCT imaging of impacted canines vary but can fall into to main categories.

1. The dental surgeons wish to know the position of the canine before surgical exposure of the canine crown, or before the extraction of the canine in some cases. This can be because of the deep lying position, horizontal orientation or possible ankylosis of the tooth.
2. Orthodontist need to have more detailed information of the severity and position of root resorption on lateral/central incisors in extraction cases, so that the choice of whether to extract lateral/central incisoris or premolars becomes clear.

## Localisation

Angulation of Impacted maxillary canines over 30 degrees does however seem to give clear indication for CBCT imaging. Angulation seen on panoramic images provides a good and clear indication for further assessment of the affected lateral or central incisors. A canine crown angulation of more than 46 degrees to the midline could suggest/indicate a higher risk of root resorption of central incisors or lateral incisors with pulpal involvement (1). Another consideration to be made is that panoramic images consistently give higher values for placement of palatally positioned canines and higher values for their angulation, giving the impression of greater displacement (6, 19).
It was discussed by Wriedt S. et al. that a small FOV to decrease DOP to the patient could make CBCT imaging justified when maxillary canine inclination exceeds 30 degrees on panoramic images, when root resorption is suspected and when the root apex is not clearly discernible in the panoramic image (3).

Wriedt S. et al found through a comparison between 2D and 3D found that 54% of canines described as buccally placed on a Panoramic image were confirmed with a CBCT scan. Also, 78% of palatally placed canines were confirmed (3). These results demonstrate the difference between Panoramic imaging and CBCT, the distortion that occurs due to the image aquistion process in panoramic imaging, and the effects on the judgment of canines localisation (20).

## Possible root resorption

Studies found and concluded that only severe root resorptions are at all visible on a panoramic image(1, 3, 11, 17). Andresen AKH. et al. found that CBCT increases canine induced root-resorption detection by 63% compared to 2D imaging alone (21).

## Indications for CBCT on a treatment decision-making level

The DIMITRA project states that CBCT could be justified for impacted maxillary canines if it impacted treatment planning, caused a less invasive approach, and increased results or predictability (7). It also states that common referal questions for CBCT in children are supernumerary teeth and impacted maxillary canines. However, evidence-based indications on these diagnostic tasks are limited.

Models are an essential part of treating patients in orthodontics, and CBCT images can not only show the relationship of teeth, but also create models that depict the relationship of the roots, root angulation and morphology (11). The presence of severe resorption on laterals or central incisors may affect therapeutic thinking when extraction of permanent teeth may be part of the preliminary treatment plan (21).

Two articles found similar percentages in the impact CBCT images had on treatment planning. Wriedt. S et al. found that 82% of treatment plans were unchanged after CBCT imaging had been done on their patients. Similarly, Christell H. et al. found that the treatment plans for their patients changed in 24% of cases after CBCT imaging. This indicates that CBCT imaging altered the treatment plan for between 1/5 - 1/4 of patients in their respective studies (3, 4).

The most significant  indication for CBCT imaging of a patient is whether it changes the treatment plan. This is considered to be a justifiable reason to expose young adults and children to increased radiation (7, 21). The articles in this review also found that whether CBCT imaging changed the treatment plan varied between clinicians. Haney, E et al. found that 3D imaging changed the treatment plan for their patients on the whole (19). Others have found that available CBCT imaging has less impact on treatment planning (4).

## Conclusion

CBCT imaging of impacted canines in children is, in most cases, unnecessary to reach a treatment plan and, therefore, should not be used as a screening method. There are however, clinical cases that merit CBCT imaging and give patients better treatment and seemingly a shorter treatment time.

The following Indications for CBCT of impacted canines have been proposed: suspicion of root resorption, insufficient information from conventional 2D radiographic imaging, imaging prior to surgical exposure in difficult cases as determined by the acting physician, or angulation of canines above 30 degrees with unclear pulpal involvement of lateral and central incisors. These decisions greatly rely on the judgement and experience of the clinician. The advantages are that CBCT imaging gives a clear consensus on diagnosis and therapeutic thinking among dental professionals (Orthodontists, surgeons and radiologists), thereby providing greater confidence in treatment planning.
In short there are no indications for CBCT to be a part of rutine treatment planning for impacted maxillary canines. More specified, evidence-based guidelines for using CBCT in children with impacted maxillary canines are warranted.

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