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*Review Article*

# Evolution of Assessment of Impacted Maxillary Canines from Plain Radiographs to Cone Beam Computed Tomography

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## ABSTRACT

**Background:** For a long time, radiographic assessment of impacted canines has been routinely carried out through plain film radiographs. However, plain radiographs tend to render distorted images of the impacted teeth due to an inherent magnification problem, and they do not allow for the accurate assessment and positioning of overlapping structures. The emergence of cone beam computed tomography (CBCT) for three-dimensional imaging of the craniofacial region has revolutionised the radiographic assessment of impacted canines at a fraction of the radiation exposure associated with multi-slice computed tomography (CT).

**Methods:** This article aims to review the available literature regarding the value of added information gained from CBCT on examining and managing impacted upper canines.

**Results:** It was concluded that CBCT is a useful imaging technique that is superior to plain radiographs in accurate localization of impacted upper canines and assessment of root resorption of adjacent teeth. Assessment of impacted upper canines through CBCT may alter the treatment planning and management of the case when compared to plain radiographs. CBCT may offer radiographic confirmation of sites of ankylosis affecting the impacted canine, however, it may produce false positive results.

**Conclusion:** Although CBCT may cause more radiation exposure to the patient when compared to conventional radiographs, it is justified to be used in the assessment of impacted canines by a number of organizations concerned with limiting the use of ionizing radiation in dentistry, providing the field of view is restricted to the upper jaw only to reduce the amount of radiation exposure.

## INTRODUCTION

An impacted tooth may be defined as failing to attain its normal position within the dental arch due to physical blockage by other teeth, bone, or fibrous connective tissue. The maxillary permanent canines are the second most commonly impacted teeth, following third molars (Al-Zoubi et al., 2017; Thilander & Jakobsson, 1968), with an incidence reported to be ranging between 1-3% of the population affected with it (Ericson & Kurol, 1986; Bishara & Ortho., 1992). Several contributing factors to maxillary canine impaction have been suggested in the literature. It is thought that the permanent canine tooth bud is too far high from the dental arch with a long path of eruption and adjacent teeth erupting earlier than maxillary canines, which are contributing to local factors to their impaction. Another factor is the loss of eruption guidance from the adjacent permanent lateral incisor tooth when the latter is diminutive or developmentally missing (Becker, 1995; Brin et al., 1986). It also has been thought that there is a genetic link to the condition, with evidence of familial tendency, occurrence of other dental conditions in association with maxillary permanent canine impaction, and higher female incidence rates (Peck et al., 1994).

By the age of 9 - 10 years old, a maxillary permanent canine should be palpable buccally in the depth of the vestibule (Ferguson, 1990), just distal to the permanent lateral incisor. If a dentist fails to palpate the tooth by that age clinically, further investigations should be undertaken (Mittal et al., 2017). Given the importance of the maxillary permanent canines, being a cornerstone to the dentition both aesthetically and functionally, an orthodontist must not spare any effort to recover these teeth and bring them into their normal position within the

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dental arch. Several proposed treatments and interventions have been suggested in the literature, depending on the position of the impacted maxillary permanent canines, the stage at which they are discovered, and the accurate assessment of the position of an impacted/ ectopic permanent maxillary canine and the presence of any associated pathology is key to successful treatment planning.

Although it is very rare for maxillary permanent canines to be developmentally missing, with an incidence reported to be about 0.08% (Brin et al., 1986), radiographic view of the area is an important and basic diagnostic tool to confirm the presence of the tooth and to assess its position within the jaw further. For a long time, radiographic assessment of impacted canines has been routinely carried out through plain film radiographs. Since plain film radiographs are two-dimensional (2D) representations of three-dimensional (3D) objects, a single 2D view of the impacted canine usually does not provide sufficient information to accurately assess the impacted tooth and the surrounding structures to assess the impacted tooth and the surrounding structures accurately. Clinicians have proposed several techniques to evaluate the position of impacted canines through plain radiographs, including parallax (Clark, 1910) and relative magnification (Chaushu et al., 1999). Despite the attempts to identify the labio-palatal position of an impacted canine, 2D plain radiographs suffer from some shortcomings. 2D radiographs tend to render distorted images of the impacted teeth due to an inherent magnification problem, and they do not allow accurate assessment and positioning of overlapping structures (Elefteriadis & Athanasiou, 1996; Waitzman et al., 1992). Furthermore, thorough assessment of the condition of the roots of adjacent teeth may not be achieved through intraoral radiographs, as they only show the proximal outline of the roots and may fail to show conditions such as root resorption taking place from palatal aspect (Follin & Lindvall, 2005).

The first medical CT scanner was invented in 1972 by British engineer Sir Godfrey Hounsfield and South African-American physicist Allan Cormack. In 1979, they were awarded the Nobel Prize for their contribution to the medical field. Since then, this technology has gone through multiple stages of improvement to increase image accuracy (Kau et al., 2005). The idea of a CT scanner, also called a computed axial tomography (CAT) scanner, is that a fan-shaped X-ray beam is projected from a source and received by a line detector opposite it. The radiation source and detector capture an image by rotating 360 about an object, then moving axially in a spiral manner to capture another image of the same object. The result is a series of images (slices) of the object that are stitched together by a computer program to produce a 3D volumetric image of the object. However, there have been limitations to using CT scans in dentistry, including the huge space they require, the increased cost, and the higher exposure to radiation doses when compared to plain film radiographs (Kau et al., 2005).

## REVIEW

The concept of CBCT is based upon the idea of projecting a cone-shaped rather than fan-shaped beam of radiation around an object that is received on an area detector rather than a line detector, which allows the computer program to produce a 3D construction of an image with a single 360 revolution of the radiation source and detector around an object (Mozzo et al., 1998; Sukovic et al., 2001) (figure.1). CBCT was developed to overcome some of the drawbacks that are associated with conventional CT scans, including reduction of the amount of exposure to radiation by the patient and reduce the cost of producing volumetric images of the craniofacial region. Since the emergence of CBCT, it has revolutionised diagnostic procedures in many branches of dentistry, including orthodontics.

When compared to 2D plain radiographs, CBCT has two main advantages. First, since the image produced by CBCT is volumetric (3D) in nature, it allows the interpreter to view the objects from all aspects without distortion from overlapping anatomical structures in the region. Second, the image produced has a measurement ratio compared to the actual object because the projected radiation beams are almost parallel (orthogonal). The machine is designed so that the object is located very close to the detector with little magnification error, which is also taken into account and corrected by the computer program as a part of the image rendering process (Mah & Hatcher, 2004).

This article aims to review the available literature regarding the value of added information gained from CBCT on examining and managing impacted upper canines.

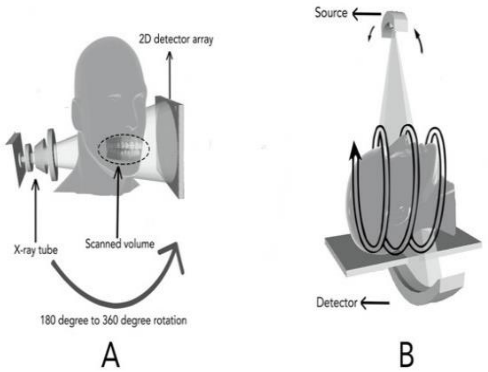

***Figure 1:*** *Volumetric images produced by exposure to a cone-shaped radiation beam. CBCT scan produces a volumetric image by exposing an object to a cone-shaped radiation beam, which is received on an area detector in a single revolution (A). Medical CT machines expose the area to a fan-shaped beam that is received on a line detector, and every single 360-degree rotation captures the image of one layer (slice) of the object and then moves axially to capture the next layer (B).*

### Localising impacted maxillary canines

The position of an impacted canine may vary greatly, which will affect the decision of an orthodontist on how to manage the condition (Motamedi et al., 2009; Stivaros

& Mandall, 2000). Therefore, Proper localisation of impacted maxillary canines is important before intervention to choose the best approach for surgical exposure as well as the most suitable orthodontic mechanics for traction and alignment (Al-Zoubi et al., 2017). The use of conventional 2D plain radiographs to assess the labio-palatal position of impacted maxillary permanent canines can be done by applying the parallax technique, in which two plane film radiographs are taken at different angles by horizontally shifting the x-ray tube to take two periapical radiographs, as originally described by Clark in 1910 (Clark, 1910). The technique was modified by others, using different combinations of other radiographic views (Keur, 1986; Southall & Gravely, 1987), while some authors suggested applying vertical rather than horizontal tube shift (Jacobs, 1999a, 1999b; Southall & Gravely, 1989). However, a study by Armstrong et al. concluded that operators could assess the labio-palatal position of the impacted maxillary canines more accurately when using horizontal rather than vertical tube shifts (Armstrong et al., 2003). An inspector applies the SLOB rule when assessing the two plain radiographs of the impacted canine taken with different angles. SLOB (same lingual opposite buccal) states that the image of an object closer to the x-ray source and farther from the film will move opposite to the direction of the tube shift and vice versa. Another concept for localisation of impacted maxillary canines is the "relative magnification", which is based on the fact that if an object is closer to the x-ray source and farther from the film relative to other adjacent objects, its image will appear magnified and relatively larger than those of the adjacent objects and vice versa. Several studies have attempted to utilise the relative magnification concept to verify the labio-palatal position of the impacted canines only from a single panoramic view with very low reliability (Fox et al., 1995; Wolf & Mattila, 1979), while others suggested taking supplemental views to accurately localise the impacted canines (Chalakkal et al., 2009). Although the magnification method is valid in principle, it has been shown that it is quite complex to utilise, with many variables to be taken into account (Chaushu et al., 1999). Despite that clinicians might be able to determine whether the ectopic canine is labial or palatal, there is no sense of depth in plain radiographs. For example, if the impacted canine is overlapping an adjacent lateral incisor palatally, how exactly far it is behind could not be determined. Also, other parameters of the impacted upper canines might influence clinical decisions, such as angulation, proximity to the midline, and vertical crown height (Stivaros & Mandall, 2000). These criteria are distorted when assessed from certain views, such as dental panograph (Ferguson, 1990; Mckee et al., 2001; Yeo et al., 2002).

Since the emergence of CBCT technology has revolutionized the localisation of impacted canines. As mentioned earlier, CBCT can provide clinicians with undistorted 3D images of the impacted upper canines and the adjacent structures with their exact dimensions. One advantage of 3D radiographs is viewing impacted canines from all space planes (Figure 2). Since then, several studies have been published to examine whether CBCT allowed clinicians to assess the location of impacted maxillary canines more objectively and with better agreement.

Botticelli et al. conducted a comparative study to assess whether the diagnosis of impacted maxillary canines differed when viewed from 2D versus 3D images. They found that operators reported greater variability regarding the location of the apex of the impacted canine, greater overlap of the canine crown to the adjacent lateral incisor, lower vertical crown height, and more labially positioned impacted canines when viewed from 3D images (Botticelli et al., 2010).

Assessment of the labio-palatal position of impacted upper canines utilising 2D plain films resulted in canines mostly localised palatally rather than labially (Ericson & Kurol, 1988; Stivaros & Mandall, 2000), and it has been shown that different techniques to localise impacted upper canines from 2D views are less sensitive in detecting buccal impactions (Mason et al., 2001; Wriedt et al., 2012). In contrast to what was reported in some studies, when impacted canines were viewed through 3D images produced using CBCT, much higher frequencies of labial impactions have been reported (Bjerklin & Ericson, 2006; Kim et al., 2017, 2012; Lai et al., 2012; Liu et al., 2008; Mohammed et al., 2020). However, this finding was not supported by the findings of other CBCT investigations, where most of the impactions were palatal (Oberoi & Knueppel, 2012; Walker et al., 2005). These conflicting results might be owed to these studies' relatively small sample sizes.

An in-vitro study for assessment of the accuracy of different imaging techniques was conducted by Serrant et al., in which they constructed a typodont with extracted human teeth to simulate upper canine impactions. 6 examiners were provided with 2D plain radiographs utilising both horizontal and vertical parallax and one set of 3D images produced through CBCT. They found that examiners were able to localise impactions with 94% accuracy when assessed through 3D images. This was statistically significantly higher than localisation through horizontal and vertical parallax, which was 83% and 65%, respectively (Serrant et al., 2014).

It appears that although experienced orthodontists are confidently assessing the labio-palatal location of the impacted maxillary canines through plain radiographs, oral surgeons tend to request further 3D views to carefully assess the labio-palatal location of the ectopic canine before intervention (Lai et al., 2013). The reason might be that surgeons aim to expose impacted canines with minimum trauma to the oral tissues, and determining the exact location of the crown is crucial before performing the exposure. Nevertheless, available evidence suggests that when 2D radiographs are being used, higher disagreements about the direction of the impaction are observed (Haney et al., 2010; Tsolakis et al., 2018).

It can be concluded that the buccal/palatal and mesial/dis tal classification of the location of impacted canines obtained from 2D views is an oversimplification in the description of the condition. Greater variabilities in the location and direction of impactions have been documented in CBCT studies (Botticelli et al., 2010; Liu et al., 2008). Other linear and angular measurements that are used for the prediction of impaction and assessment of severity might not be accurate enough when obtained from plain films due to their inherent distortion, magnification errors, overlapping of anatomical structures, and the effect of incorrect positioning of the patient head. On the other hand, linear measurements taken from 3D images produced by CBCT are more accurate and reliable (Lascala et al., 2004; Mohammed et al., 2020; Moreira et al., 2009). Additionally, more precise and accurate localisation with a higher agreement between operators suggests a more objective assessment through CBCT (Alqerban et al., 2011; Haney et al., 2010; Liu et al., 2008; Pittayapat et al., 2014; Serrant et al., 2014; Tsolakis et al., 2018).

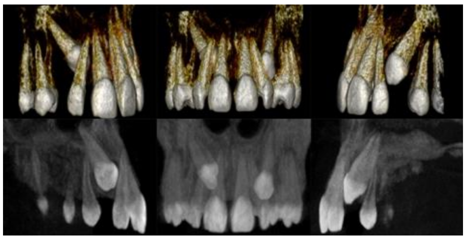

***Figure. 2:*** *CBCT scan of bilaterally impacted maxillary canines. The top row shows a three-dimensional surface rendering of the maxillary teeth with the position of the impacted canines demonstrated without any distortions. The bottom row shows a Frontal (coronal) two-dimensional view of the maxillary teeth. It reveals the overlap of the impacted canines with the adjacent incisors, and the angle to the midline can be measured (middle photo). Sagittal views of both canines show how close the impacted canine is to the roots of the incisors from the palatal aspect (right and left photos)***.**

## Root resorption of adjacent teeth

Resorption of the roots of adjacent teeth is a serious potential risk associated with impacted maxillary canines (Ericson & Kurol, 1986) that might alter treatment outcomes and limit treatment options. This degenerative process occurs on the external surface of the roots and is thought to be due to the increased pressure brought by the ectopic canine (Ericson et al., 2002; Fuss et al., 2003). Careful and accurate assessment of the presence and severity of root resorption associated with maxillary ectopic canines must be carried out before treatment planning and intervention. Aenordenram & Anneroth have carried out one of the earlier studies concerned with the condition using plain radiographs, they reported in their study that none of the incisors adjacent to ectopic canines showed any signs of resorption (Äênordenram & Anneroth, 1982). Ericson and Kurol initially reported that complications such as root resorption of adjacent incisors rarely take place in association with impacted maxillary canines (Ericson & Kurol, 1986). This underestimation of root resorption associated with impacted canines that were reported in earlier work could be owed to the fact that the assessment was carried out using intraoral plain radiographic views, which is not very useful in detecting resorption taking place from lingual/ palatal aspects (Follin & Lindvall, 2005). In the following investigation, Ericson & Kurol used supplemental polytomographic views, which allowed them to look at the palatal aspect of lateral incisors, and reported an incidence of 12.5% of resorption of these teeth (Ericson & Kurol, 1987). They also have carried out one of the earlier studies utilising CT technology to look at root resorption of incisors associated with ectopic canines. They reported that resorption was more frequent than what was documented in investigations based solely on 2D plain views, affecting 38% of adjacent laterals and 9% of centrals, with severe resorption in 60% and 43% of these teeth, respectively (Ericson & Kurol, 2000). A more recent study with a larger sample size reported severe root resorption in about 12% of laterals and 2% of centrals adjacent to upper-impacted canines (Cernochova et al., 2011). When compared to plain radiographs, this increase in the detection of root resorption could be owed to the ability of CT images to provide detailed 3D views of the teeth that are unobstructed by overlapping anatomical structures (Elefteriadis & Athanasiou, 1996; Preda et al., 1997). Nevertheless, despite the benefits CT scans brought to the diagnosis of impacted upper canines, the high amount of radiation exposure and high cost were reasons to limit their routine use in the diagnosis of impacted canines (Chaushu et al., 2004; Schulze et al., 2004; Walker et al., 2005).

Since the introduction of CBCT to the market, several studies have looked into root resorption of teeth adjacent to ectopic maxillary canines. When looking at root resorption associated with ectopic canines, CBCT studies also reported higher prevalence compared to what was reported in CT investigations, suggesting CBCT is superior to CT in offering higher resolution and being more sensitive to detecting root resorption (Dogramaci et al., 2015; Jawad et al., 2016). In contrast to reports based on evaluation through plain radiographic views, CBCT studies support the notion that root resorption of adjacent teeth is a common condition, affecting almost half the patients with impacted maxillary canines (da Silva Santos et al., 2014; Dogramaci et al., 2015; Kim et al., 2012). One study compared detecting root resorption associated with impacted upper canines when assessment is made through plain radiographs vs CBCT views and found that 3D images showed significantly higher prevalence (Botticelli et al., 2010). Studies based on evaluating CBCT images reported root resorption prevalence ranged between 16 - 67.6 % of laterals, 5.22 - 26.8 % of centrals, and some studies found evidence of resorption affecting 0.75 - 11.7 % of premolars, which was a problem associated with an approximation of the impacted canine to the roots of the affected teeth rather than being a result of a widened dental follicle around the crown of the ectopic canine (da Silva Santos et al., 2014; Dogramaci et al., 2015; Hadler-Olsen et al., 2015; Lai et al., 2012; Liu et al., 2008; Mohammed et al., 2020; Walker et al., 2005; Wriedt et al., 2012; Yan et al., 2015). It was demonstrated in one in-vitro study in which they used a dry pediatric skull, that CBCT has higher sensitivity and specificity for detection of root resorption adjacent to impacted upper canines when compared to conventional 2D panoramic views, and observers were able better to assess the severity of resorption from CBCT views (Alqerban et al., 2009). Furthermore, clinicians have examined the severity and extent of root resorption with higher agreement from CBCT views when compared to plain radiographs (Alqerban et al., 2011), suggesting a more precise and objective assessment.

### Influence on Treatment Planning and Clinical Efficacy

A clinician may choose from several treatment options to manage impacted upper canines, including interceptive procedures, surgical exposure with orthodontic traction, surgical repositioning, surgical removal, or observation without any intervention (Counihan et al., 2013). Local factors that might influence the clinical approach are the location, angulation of the impacted canine, proximity to the incisors, and the condition of adjacent teeth, especially the existence and severity of root resorption (Alqerban et al., 2013a). Therefore, careful and accurate examination of the ectopic canine and the neighbouring teeth, both clinically and radiographically, is crucial to formulate the most appropriate approach to managing the problem. Several studies looked into the value gained from obtaining 3D scans before intervention in canine impaction cases and whether standard 2D views were enough to diagnose and treatment plan. Bjerklin and Ericson reported a change of treatment plan in almost 44% of patients with impacted canines when 3D images were obtained, which was mainly due to a change of extraction choice after clearly assessing root resorption on adjacent lateral incisors (Bjerklin & Ericson, 2006). Haney et al. reported that orthodontists changed their clinical approach to managing impacted canines in 27% of the patients when 3D images were provided, with alteration in initial traction mechanics in about one-third of the impacted canines that were decided to be recovered when 3D images were provided (Haney et al., 2010). Clinicians were shown to lean more toward observing the problem when the assessment was based on 2D views. In contrast, 3D views influenced approaching cases of impacted canines with more active interventional treatment modalities (Botticelli et al., 2010), and 3D views resulted in the decision of more canines to be recovered rather than surgically removed (Wriedt et al., 2012).

On the other hand, some authors criticised the added value of obtaining 3D images for impacted canine cases and argued that most cases could be effectively diagnosed and managed with standard 2D views that were routinely obtained initially before orthodontic treatment. Although Alqerban and co-workers found no statistically significant alteration of preoperative surgical and orthodontic planning in the management of impacted upper canines, they reported higher confidence associated with 3D-based treatment planning, a change in therapeutic plans in about 80% of the cases and a significant change in orthodontic traction mechanics in cases where surgical exposure was to be carried (Alqerban et al., 2014, 2013b). Christell et al. conducted a survey that included 112 orthodontists looked into the change in orthodontic treatment decisions between 2D and 3D images; they found a 24% difference in management decisions when the case was interpreted with different imaging modalities, which was statistically non-significant (Christell et al., 2017). However, their results must be viewed cautiously, as they only included impacted upper canine cases in patients with good occlusion in class I molar and incisors relationship with no or minimum crowding. These cases seem to be on the milder segment of the complexity scale of such cases, which does not represent all the encounters that a clinician may face in real situations.

Despite the conflicting evidence on the clinical effectiveness of using CBCT technology in the diagnosis and management of impacted canine cases, one cannot deny the hard evidence that it provides improved and more accurate visualisation of the ectopic canine and the condition of surrounding structures when compared to conventional plain radiographs, which is an essential step in treatment planning and management of such cases. An analysis of possible factors that lead to failure of treatment of impacted upper canines showed that inaccurate localisation of the ectopic canine and failure to detect root resorption of adjacent incisors, which was mostly based on 2D plain views, contributed to 48.6% and 16.2 % of failure of treatment, respectively (Becker et al., 2010). From all that was discussed in this section, one cannot underestimate the clinical benefits of using CBCT scans over conventional 2D plane views in the overall evaluation of impacted maxillary canines before deciding the best possible clinical approach.

### Impacted canine ankylosis and invasive cervical root resorption

A tooth may become ankylosed when an area of its root cementum and/or dentin fuses with the surrounding alveolar bone after losing periodontal tissue. There is a risk of impacted maxillary canines becoming ankylosed; this risk may be higher for those canines that remain impacted for a longer duration in older patients (Becker & Chaushu, 2003). Ankylosed impacted canines may not respond to applied orthodontic traction forces, leading to failure of its recovery, adverse effects on the occlusion, and, ultimately, failure of orthodontic treatment. Since impacted canines may not be accessible for clinical assessment for signs of ankylosis, it would be useful if clinicians were able to radiographically examine the roots of impacted canines and attempt to detect areas of ankylosis to manage the problem appropriately. According to Andersson et al., plain radiographs are not quite useful in detecting areas of obliteration of PDL space, which may indicate ankylosis, affecting areas other than the proximal aspects of the tooth (Andersson et al., 1984).

Since 3D images allow operators to look at the different structures surrounding the roots of impacted canines, some authors looked into the usefulness of CBCT images to reveal areas of discontinuity of periodontal ligament (PDL) and ankylosis along the root surface of impacted canines. Doubt has been raised in literature regarding whether CBCT resolution is high enough to suggest that lack of PDL in an area around a root detected on a CBCT scan necessarily means an area of ankylosis (Garib et al., 2014). Despite the high sensitivity of CBCT images to detect areas of ankylosis when compared to histological sections of ankylosed teeth, false positive results have been found (Ducommun et al., 2018). Plaisance and coworkers published a recent study in which they were able to successfully detect points of ankylosis by performing a 3D surface rendering of the impacted canines and manipulating the volumetric images with a certain computer program, thus allowing them to identify ankylosed canines and alter their management approaches (Plaisance et al., 2017). It seems that there is a limited usefulness of CBCT to accurately identify ankylosed teeth and clinicians should not solely rely on CBCT images to give a definitive diagnosis, as this might result in unnecessary complex treatment choices. However, CBCT provides an adjunctive method of assessing the possibility of an ankylosed impacted canine, especially if the tooth does not respond as expected to the applied orthodontic traction.

Another condition that might give the same clinical response to orthodontic traction of an ankylosed impacted canine has been reported in the literature and is called invasive cervical root resorption (ICRR). Heithersay described it as a rare and aggressive form of external root resorption, which is a replacement resorption that may start as a bony invasion in a specific site in the cervical area through the dentin, usually without pulpal involvement in the earlier stages (Heithersay, 1999). Becker et al. looked at possible causes of orthodontic treatment failure of impacted maxillary canines. They reported that ICRR does not prevent the physiologic response to orthodontic traction but results in mechanical interlocking between the tooth and surrounding bone due to the invasion of bone into the tooth structure, which presents a clinical response that resembles ankylosis. They concluded that it is not uncommon for clinicians to overlook ICRR, especially when the impacted canine is assessed through plain radiographs. They recommended using CBCT to detect ICRR and manage the condition properly (Becker et al., 2013).

### Risk of ionising radiation and justification of obtaining CBCT scans

One of the risks of using radiation-based imaging in medicine is exposing the patient to ionising radiation, which may contribute to stochastic risk of carcinogenesis, and chances increase as the effective radiation dose (ERD) increases. The risks associated with the increased effective radiation doses from CBCT are considerably higher in children (Theodorakou et al., 2012), who usually comprise the larger percentage of the population seeking orthodontic treatment. CBCT has the advantage of lower radiation doses when compared to multi-slice CT (Carrafiello et al., 2010) but still exposes patients to a higher dose than plain radiographs (Suomalainen et al., 2008). However, it is reported that the effective radiation doses of CBCT scans vary greatly, depending on the machine used, the resolution of the scan, and the chosen field of view (FOV) diameter, as summarized in Table 1 (American Association of Oral and Maxillofacial Radiology, 2013). Therefore, operators may reduce the radiation exposure to the patient by limiting the FOV to the area of interest and with the minimum resolution necessary to assess the different structures. However, clinical justification and assessing the benefits and risks of performing CBCT scans to obtain diagnostic information must be carried out on an individual basis.

The current North American guidelines for the use of CBCT in dental and maxillofacial imaging, published by the American Association of Oral and Maxillofacial Radiology (AAOMR) in 2013, have reported that the use of CBCT imaging in the diagnosis and treatment planning of impacted canines is indicated and justified (Radiology 2013). The European regulations known as the SedentexCT project, published by the European Commission, have indicated the use of CBCT imaging in cases of impacted canines only when the information that can be gained from the lower radiation doses conventional radiographs may not be sufficient to assess and manage the condition (European Commission, 2012). Another European organisation (DIMITRA project) aiming at investigating and reducing dental and maxillofacial radiation-related risks in children, radiation-related risks in children has published a position statement in 2017. They reported that the available evidence indicates the use of CBCT in diagnosing impacted canines in children (Oenning et al., 2018). All the above-mentioned guidelines recommended using a restricted field of view (FOV) to the area of interest, being either full or half jaw, to reduce radiation exposure and apply the ALARA (as low as reasonably achievable) principle.

***Table 1:*** *Ranges of effective radiation doses (measured in micro Sieverts) of different CBCT scans compared to multi-slice CT and two conventional views.*

| Radiographic view | Effective radiation dose (μSv) |
|---|---|
| Multi-slice CT | 426 – 1160 |
| Craniofacial CBCT (FOV > 15 cm) | 52 – 1073 |
| CBCT of the face (FOV = 10 – 15 cm) | 61 – 603 |
| CBCT of the jaws (FOV < 10 cm) | 18 – 333 |
| Cephalogram | 2- 10 |
| OPG | 6 – 50 |

(FOV = field of view, OPG = orthopantomogram)

## CONCLUSION

CBCT is a valuable imaging technique for oral surgeons and orthodontists in diagnosing and managing impacted maxillary canines. It is superior to conventional radiographs in accurately localising impacted maxillary canines and assessing root resorption of the adjacent teeth.

The higher agreement of findings among clinicians suggests a more objective overall assessment.

The information gained from CBCT imaging in impacted canine cases may affect clinical management and improve treatment efficacy.  CBCT may help confirm an ankylosed impacted canine and evaluate areas of the root that may be involved, especially if it has shown no response to orthodontic traction. However, care must be exercised, as CBCT may show false positive sites of ankylosis.

There is a justification for obtaining CBCT scans for impacted upper canines, and the use of restricted FOV to limit the scan to the maxilla only is enough and emphasised to reduce the amount of exposure to ionising radiation and follow the ALARA principle in medical imaging.

## AUTHOR CONTRIBUTION

The author confirms sole responsibility for the writing of this review article.

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## DECLARATIONS

### Ethical Considerations

Not Applicable.

### Participants Consent

Not Applicable.

### Conflict Of Interest

The author declares that no financial support was received from any organisation for the submitted work, and no other relationships or activities could have influenced it.

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## OPEN ACCESS

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