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College of Dentistry

Prevalence of Impacted Canine by Cone Beam Computed Tomography

(Review of Literature)

A project submitted to

The college of Dentistry, University of Baghdad , Department of Oral Diagnosis/ Oral and Maxillofacial Radiology in partial Fulfillment of the requirements for the Bachelor of Dental Surgery

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Dedication

I dedicate this project to my family and to my supervisor

Dr. Areej Ahmed, from whom we learned a lot.

Acknowledgment

First and foremost, praises and thanks to Allah Almighty for helping me fulfill a part of my dream, for his blessings throughout my work to complete it successfully. I would like to extend my deepest respect and gratitude to the Dean of College of Dentistry, University of Baghdad, Prof. Dr. Raghad Al-Hashimi.

I would like to show my deep and sincere gratitude to my research supervisor Dr. Areej Ahmed for her advice, encouragement, and guidance in planning and conducting this project.

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List of Abbreviations

Abbreviation	Meaning
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
DCT	Dental computed tomography
CBVT	Cone beam volumetric tomography
VCT	Volumetric computed tomography
3D	Three dimensional
2D	Two dimensional
MPR	Multiplanar reformation
DVR	Direct volume rendering
MIP	Maximum intensity projection

IVR	Indirect volume rendering
MDCT	Multidetector computed tomography
OPG	Orthopantomogram
FOV	Field of view
μSv	Microsieverts
TMJ	Tempromandibular joint
Etc	Etcetera
SLOB	Same Lingual Opposite Buccal
RR	Root resorption
EARR	External apical root resorption

Introduction

CBCT is also frequently called dental computed tomography (DCT) or cone - beam volumetric tomography (CBVT) or volumetric computed tomography (VCT). Farman prefers CBCT because this describes the principles of operation rather than its application in dentistry or the resulting datasets **(Scarfe and Farman, 2008).**

The benefits of good image quality, volumetric analysis, short scan times, and relatively less radiation dose than conventional medical CT, has resulted in greater ubiquity as an imaging modality within all disciplines of dentistry. Many fields, including orthodontics, oral surgery, implant dentistry, periodontics, and endodontics find unique utility of the 3-dimensional reconstructions provided by CBCT **(Rungcharassaeng *et al*, 2007; Roe *et al*, 2012).**

The maxillary canine is the second most commonly impacted tooth, after the third molar, with an incidence rate that ranges from 0.8% to 2.8% **(Shin *et al*, 2019).**

Conventional 2D radiographs – periapicals, occlusals, panoramics – are sufficient to identify an impacted tooth and using the SLOB rule (same lingual, opposite buccal) to localize the tooth to one side of the alveolus or the other. CBCT not only provides this information, but it also shows the proximity of the impacted tooth to adjacent roots **(Nervina, 2012).**

Cone-beam computed tomography (CBCT) with reduced radiation doses compared with those of medical CT, whilst offering three-dimensional (3D) imaging capability for displaying head and neck structures in detail has been introduced. The rapid development of CBCT scanning combined with 3D rendering techniques produces high-resolution images that have been proven to be useful for the diagnosis of impacted canines, treatment planning, and the identification of associated complications, such as root resorption, in adjacent incisors **(Alqerban *et al.*, 2011).**

CBCT overcomes the limitations of conventional two-dimensional (2D) imaging **(Walker *et al.*, 2005; Liu *et al.*, 2008; Alqerban *et al*., 2011).**

Aim of the study: To detect the distribution of impacted canine and its localization by CBCT.

Chapter One: Review of Literature

1.1. History of CBCT

Diagnostic imaging over the last few decades, turned out to be much more re fined owing to addition of various imaging technology with complex physical principles. Three-dimensional imaging (3D) evolved to meet the demands of advanced technologies in delivering the treatment and at the same time responsible for the evolution of new treatment strategies. Considering the limitations (superimpositions, distortions etc.) of two-dimensional (2D) radiography (figure 1.1), which was the backbone of diagnostic imaging for many years, doubt exists that it will continue to contribute in the future **(Venkatesh and Venkatesh Elluru, 2017).**

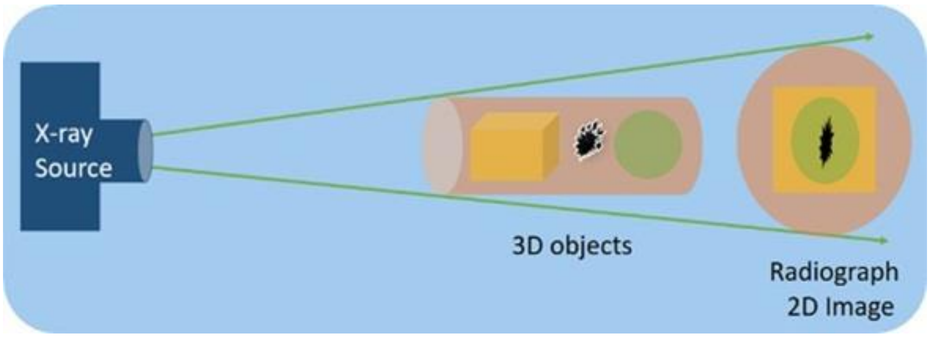

Figure 1.1.2D Imaging limitations **(Venkatesh and Venkatesh Elluru, 2017).**

Computed tomography was available for 3-dimensional dental imaging in the 1980s, but due to the high cost, limited access, and radiation exposure, utilization was limited to management of craniofacial anomalies, complex surgeries, and other unique dental situations **(Harrison and Farmer, 1978; Cho *et al*., 1995).**

It is only since the late 1990s that it has become possible to produce clinical systems that are both inexpensive and small enough to be used in the dental office. Four technologic factors have converged to make this possible: (1) the development of compact high quality flat-panel detector arrays, (2) reductions in the cost of computers capable of image reconstruction, (3) development of inexpensive x-ray tubes capable of continuous exposure and, (4) limited volume scanning (e.g., head and neck), eliminating the need for Sub second gantry rotation speeds **(White and Pharoah, 2009)**

There can be no denying that Cone Beam Computerized Tomography (CBCT) is an in-office diagnostic imaging technology that has taken maxillofacial imaging by storm and the most significant advance in extraoral dental imaging since the introduction of rotational panoramic radiography. The significant advancements and applications provided by this technology do not compete with standard digital radiographic applications. Rather, CBCT is a complementary modality for specific applications **(Farman and Scarfe, 2018).**

Figure1.2. The first commercially available maxillofacial cone beam computed tomography units in the United States. (A) Supine type. (B) Seated type **(Mallya and Lam, 2018).**

1.2. Principles of CBCT

CBCT machine uses a cone-shaped beam and a reciprocating solid-state flat panel detector, which rotates once around the patient (Figure 1.3.), 180-360 degrees, covering the defined anatomical volume (complete dental/maxillofacial volume or limited regional area of interest). This single scan (rotation) captures planned data (180-1024 2D images, similar to lateral cephalometric images, each one 's marginally offset) further reducing the absorbed x-ray dose from 6 to 15 times in comparison to CT **(Venkatesh and Elluru, 2017)**. These raw data are reconstructed by computer algorithm to generate cross sectional images **(Kailash, 2014).**

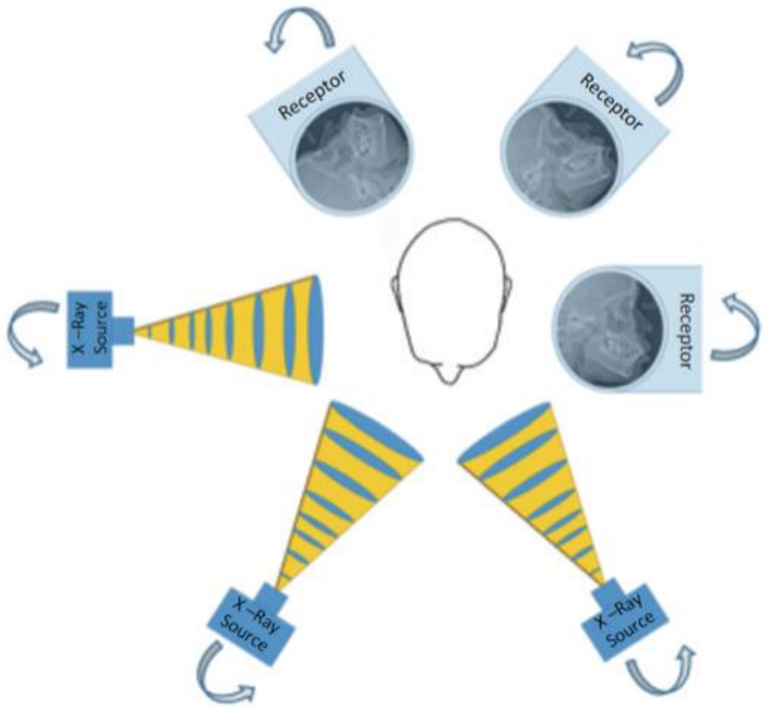

Figure 1.3.CBCT Principle of basic image acquisition where in X-ray source and Image receptor reciprocate around patient 180 – 360 degrees to acquire 180– 1024, 2D cephalometric images **(Venkatesh and Elluru, 2017).**

1.3. Field of View:

FOV refers to the anatomical area that will be included in the data volume or the area of the patient that will be irradiated **(Farman *et al.*, 2011; Brown *et al.*, 2014).** Depending upon the type of machine/detector, and the geometry of the x-ray beam, the FOV could be classified as small or limited, medium and large **(Scarfe *et al* , 2012; Abramovitch and Rice, 2014; White and Pharaoh, 2014).**

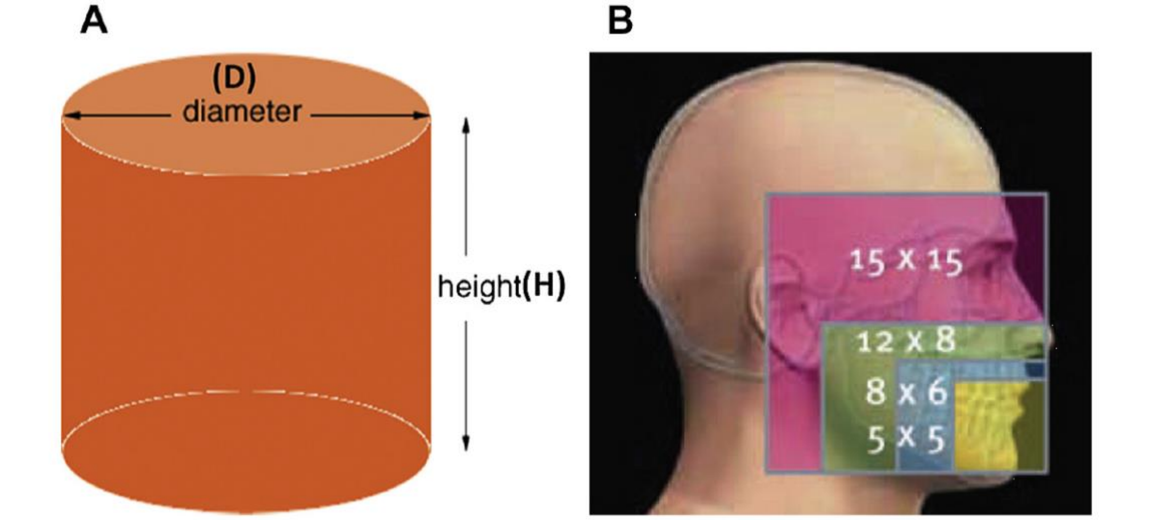

Figure 1.4.(A) Cylindrical shape and measurement characteristics of the field of view (FOV) for CBCT. (B) The different FOV option sizes **(Abramovitch and Rice, 2014).**

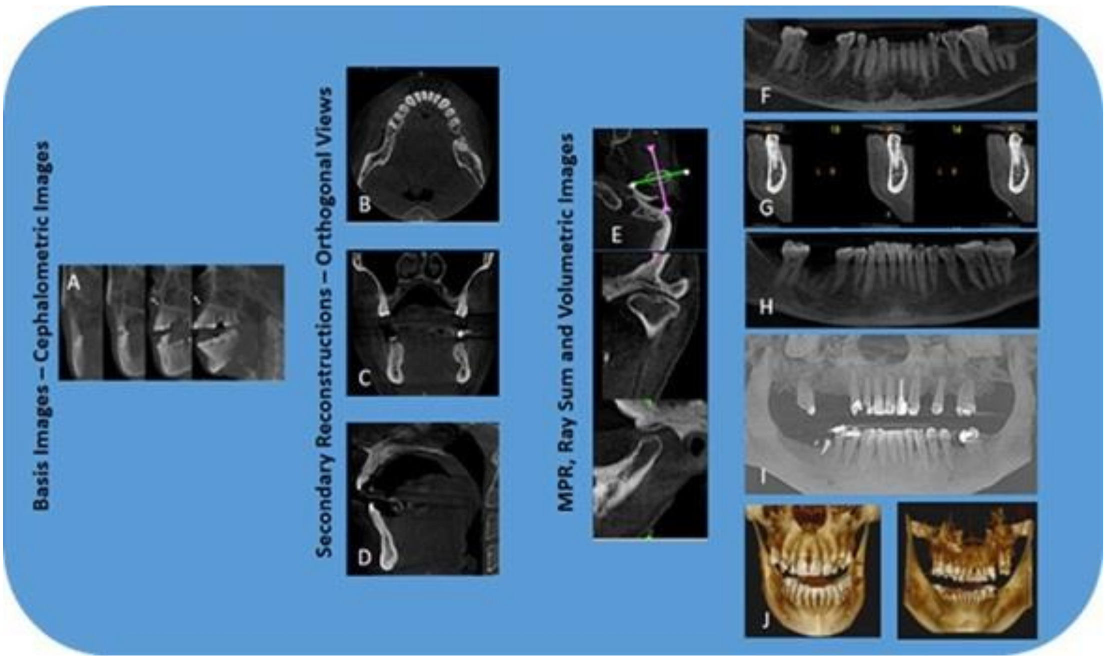

Figure 1.5.CBCT: Image acquisition and display modes. Acquired 2D Basis images (A) are used for Secondary reconstruction of axial (B), coronal (C) and sagittal (D) views (orthogonal views). Other display modes available in CBCT include (i) multiplanar reformatted (MPR) consisting of Oblique slices (E) Curved slice (F) and Cross sectional views (G); (ii) Ray sum comprising images of increased section thickness (H); and (iii) volumetric images consisting of Direct volume rendering (DVR), the most common of which being maximum

intensity projection (MIP) (I) and Indirect volume rendering (IVR) (J) **(Venkatesh and Venkatesh Elluru, 2017).**

1.4. Patient Orientation

Most CBCT units operate with the patient in a standing or sitting position. Standing/seating units are typically compact (i.e., small physical footprint), allowing them to be placed in private dental clinics or other environments where little space is available. Few CBCT models are available where the patient is scanned in the supine position, as in MDCT **(Scarfe and Angelopoulos, 2018).**

Standing units may not be able to be adjusted to a height to accommodate wheelchair-bound patients. Seated units are the most comfortable; however, fixed seats may also not allow scanning of physically disabled or wheelchair-bound patients. Because scan times are often greater than that used with panoramic imaging, perhaps more important than patient orientation is the head restraint mechanism used **(White and Pharoah, 2009).**

1.5. Radiation Dosage:

CBCT unit results in higher radiation exposure than traditional dental radiograph; its radiation dose is lesser than that of medical Multichannel CT. Reducing the size of the irradiated area by collimation of the Primary X-Ray beam to the area of interest minimizes the radiation dose. Most CBCT units can be adjusted to scan small regions for specific diagnostic tasks. Radiation of a single CBCT scan is about 537 microsieverts (mean value) **(Kailash, 2014).**

The radiation doses with each machine are going to be different due to: variability in device type, imaging protocols including the field of view, and exposure parameters (Ma,Kv). Effective doses for the various modalities are listed in Table 1.1**(Kadioglu and Currier, 2019).**

Table 1.1 Effective doses from CBCT **systems (Kadioglu and Currier, 2019).**

Field of view (FOV)	**Effective dose range**
Small and medium FOV **Volumes <10 cm**	**11-674**

Large FOV **Volume >10 cm**	**30-1073**

1.6. Advantages of CBCT

1.6.1. X-ray beam limitation: reducing the size of the irradiated area by collimation of the primary x-ray beam to the area of interest minimizes the radiation dose. Most scanners can be adjusted to scan specific small regions or to include the entire craniofacial complex, depending on the required task (Figure 1.6.) **(Macleod and Heath, 2008).**

1.6.2. High-Speed Scanning: The time for the CBCT scanning is substantially reduced and, for most equipment, is less than 30 seconds. This is because the CBCT requires only a single scan to capture the necessary data **(White and Pharoah, 2009).**

1.6.3. Size and Cost: CBCT equipment has a greatly reduced size which can be easily accommodated in dental office. Cost is almost one fourth to one fifth to the Cost of CT **(White and Pharoah, 2009).**

1.6.4. Low Patient Radiation Dose: As per International Committee on radiation protection, the effective dose for CBCT range from 52 to 1025 micro-sieverts (μSv) which 96%–51% less than of Conventional head CT (range 1400–21000 (μSv). Moreover, in CBCT X-ray beam can be collimated to reduce the irradiated area, thereby reducing the dosage and exposure. Patient radiation dose can be lowered by providing thyroid and cervical spine shielding **(Kailash, 2014).**

1.6.5 Display Modes Unique to Maxillofacial Region: Besides providing interrelated images in orthogonal planes CBCT data sets can be segmented nonorthogonal multiplanar reformatted (MPR) to provide oblique, curved planar reformation (distortion free simulated panoramic images) and, serial cross sectional reformation, all of which can be utilized to accentuate precise anatomic structures and diagnostic functions. These features are very essential considering the intricate oral& maxillofacial anatomy **(Scarfe and Farman, 2008; White and pharaoh, 2014).**

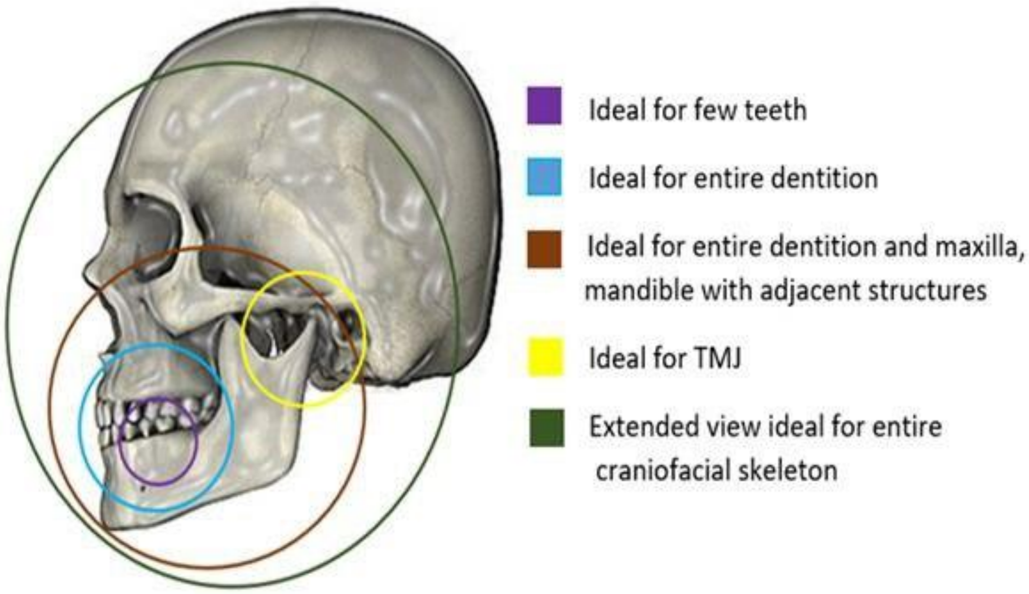

Figure1.6. Showing the capability of CBCT machines to collimate (select FOV) the X-ray beam to suit the needs of individual clinical situations **(Venkatesh and Venkatesh Elluru, 2017).**

1.6.6. Interactive Analysis: Acquired scan data are reconstructed through certain software which also provide extended applications for implant site assessment, Cephalometric analysis. Cursor driven measurements are also possible **(Kailash, 2014).**

1.6.7. Reduced image artifact: Availability of artifact suppression algorithms and increasing number of projections have led to low level of metal artifact, mainly in secondary reconstructions intended for seeing the jaws and teeth **(Cohnen *et al*., 2002).**

1.7. Limitations of CBCT:

1.7.1. Image Noise: The cone beam projection acquisition geometry results in a large volume being irradiated with every basis image projection. A large portion of the photons undergo Compton scattering interactions and produce scattered radiation. Most scattered radiation is produced omnidirectionally and recorded by pixels on the cone beam area detector; it does not reflect the actual attenuation of an object along a specific path of the x-ray beam. This additional recorded x-ray attenuation, reflecting nonlinear attenuation, is called noise and contributes to image degradation (figure 1.8.) **(White and Pharoah, 2009).**

In homogeneity of X-ray Photon and increased X-ray beam divergence also causes image noise **(Kailash, 2014).**

1.7.2. Poor Soft Tissue Contrast: X-ray photon intensities vary according to the tissue through which it is transmitted. It differs with the density of the tissue, Anatomic number and thickness **(Kailash, 2014).**

Three factors limit the contrast resolution of CBCT, which include increased image noise, the divergence of the x-ray beam and numerous inherent flat-panel detector-based artifacts (figure 1.9.) **(Venkatesh and Venkatesh Elluru, 2017).**

1.7.3. Artifacts: An image artifact may be defined as a visualized structure in the reconstructed data that is not present in the object under investigation. Generally speaking, artifacts are induced by discrepancies between the actual physical conditions of the measuring set-up (i.e. the CBCT scanner's technical composition plus the composition, position and behavior of the object under investigation) and the simplified mathematical assumptions used for 3D reconstruction **(Schulze *et al*., 2011).**

A. Metal artifacts: are the result of exuberant absorption of X-rays by the metal, and the inability of the reconstruction algorithm to cope with this, leading to dark and bright regions and streak in the vicinity of the metal (Figure1.7.). Metal artifacts can severely affect the visibility of structures in the vicinity of, or between metal objects. Therefore, metal objects should be removed prior to scanning if possible (e.g., removable prosthesis) **(Scarfe and Angelopoulos, 2018).**

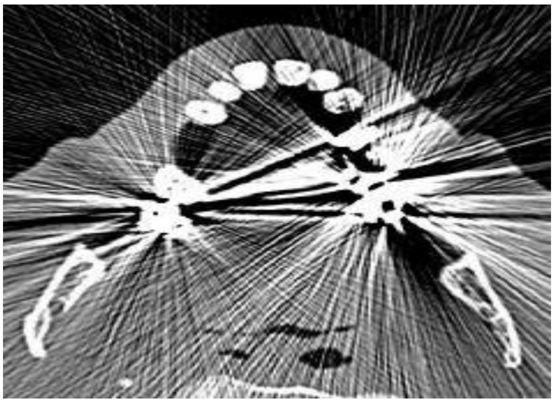

Figure 1.7. Metal streak artifacts due to the presence of amalgam dental fillings **(De Man *et al.*, 2000).**

B. Patient motion: The fact that the patient is in a sitting or standing position for most units, along with the relatively long scan time (usually 15-20 s), can result in slight or more severe motion blurring. While slight movements (e.g., swallowing, regular breathing) does not lead to considerable image degradation, excessive movement can lead to severe distortion, possibly requiring retakes **(Spin-Neto *et al*., 2013; Nardi *et al*., 2016).**

C. Ring artifacts: visible as concentric rings centered around the location of the axis of rotation that result from imperfections in scanner detection or poor calibration. They are most prominent when homogeneous media are imaged. Owing to the circular trajectory and the discrete sampling process, these inconsistencies appear as rings in the planes coplanar with the movement plane of the source (axial planes in CBCT) **(Dwivedi *et al.*, 2015).**

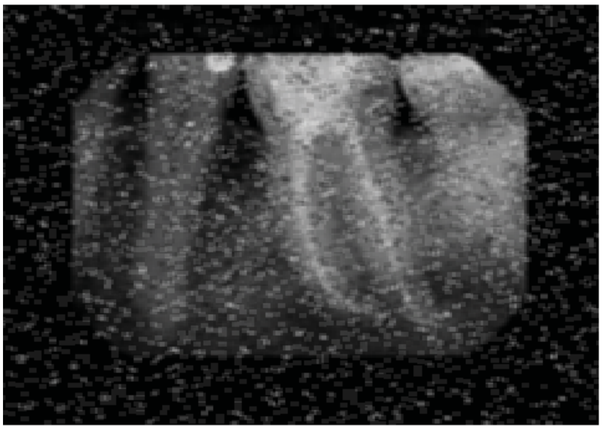

Figure 1.8. Image Noise **(Thakur *et al*., 2016).**

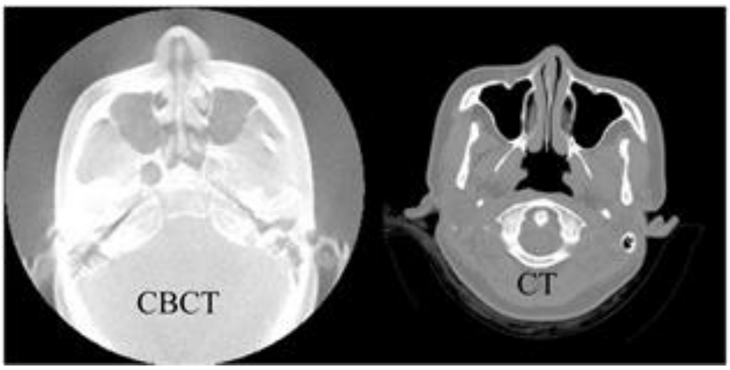

Figure 1.9. Typical CBCT vs. CT image in which appear the poor tissue contrast of CBCT **(Kabaliuk *et al*., 2017).**

1.8. Application of CBCT in Dentistry:

1.8.1. Oral and Maxillofacial Surgery:

CBCT imaging offers improved intra- and inter-observer reliability for the identification of some facial anatomical features. Safe and optimal removal or transplantation of impacted wisdom teeth and localization of impacted canines are enhanced with the use of CBCT. In oral surgery, CBCT is superior in generating images to locate root position and proximity of impacted third molars to the inferior alveolar nerve, compared to 2-dimensional cephalographs as well as other structures such as the infra-orbital artery **(Chien *et al.*, 2009).**

The relationship of the inferior alveolar canal to the roots of mandibular third molar teeth is of importance when attempting to minimize the likelihood of nerve damage that may lead to permanent loss of sensation to one side to the lower lip. Thus, accurate assessment of the position of the canal in relation to the impacted third molar may reduce injuries to this nerve. Volumetric rendering with IAC annotation or "tracing" in combination with cross-sectional imaging provides useful visualization of the relationships of anatomic structures in these circumstances **(white and pharaoh, 2019).**

1.8.2. Orthodontics:

CBCT offers superimposition free images that are self-corrected for magnification, with a practical 1:1 measuring ratio, for morphometric analysis of structures and anatomic relationships essential for dealing with various orthodontic demands **(Venkatesh and Elluru, 2017).**

CBCT imaging is used in the diagnosis, assessment, and analysis of maxillofacial orthodontic and orthopedic anomalies. The most common conditions in which CBCT is useful are the identification of dental structural anomalies, such as root resorption and display of the position of impacted and supernumerary teeth and their relationships to adjacent roots or other anatomic structures **(White and Pharaoh, 2019),** skeletal growth patterns, dental age estimation, tooth inclination and torque, determining available alveolar bone width for buccolingual movement of teeth, upper airway assessment, and for planning orthognathic and facial orthomorphic surgeries **(Venkatesh and Elluru, 2017).**

While 2D radiographs only provide visualization of the apex and the mesial and distal root surfaces, CBCT imaging enables the visualization of buccal and lingual root surfaces. This has led to the discovery that root loss is not only present at the root apex but often presents as a slanting root loss on surfaces adjacent to the direction of tooth movement. This finding highlights the efficacy of the 3D rendering capacity of CBCT for accurate diagnosis of both external apical root resorption (EARR) and other previously uncharacterized types of root resorption **(Kapila and Nervina, 2015).**

CBCT data can be used to produce 3D digital study models without the need for alginate impressions. It avoids patient discomfort and saves orthodontist's valuable chair time. These models are of higher diagnostic value than other digital models because it includes not only the tooth crowns but also roots, impactions, developing teeth and alveolar bone **(Agrawal, 2013).**

CBCT in Orthodontic is not indicated for Planning the placement of temporary anchorage in orthodontics and for routine orthodontic diagnosis **(Whaites and Drage, 2020).**

Some of the orthodontic uses include assessment of palatal bone thickness, skeletal growth patterns, dental age estimation, visualization of impacted teeth (figure1.10.), tooth inclination and torque, determining available alveolar bone width for buccolingual movement of teeth, upper airway assessment, and for planning orthognathic and facial orthomorphic surgeries **(Aboudara *et al.*, 2003; Peck *et al*., 2007).**

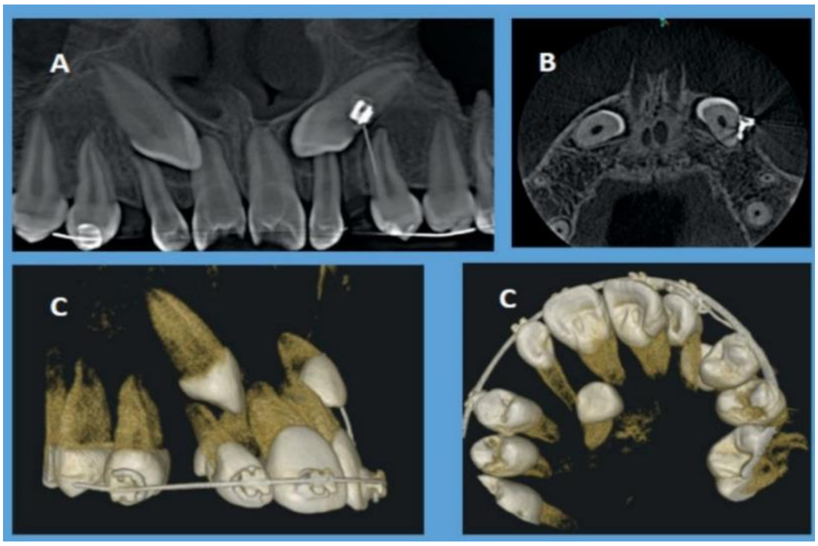

Figure 1.10. Orthodontics applications revealing evaluation of impacted canine by CBCT **(Venkatesh and Venkatesh Elluru, 2017).**

1.8.3. Implant Site Assessment:

Successfully providing dental implants to patients who have lost teeth and frequently the surrounding bone relies on the careful gathering of clinical and radiological information, on interdisciplinary communication and on detailed planning **(Worthington *et al*., 2010).**

Most commonly 2D radiographs and in specific cases, conventional CT were employed for assessment of the implant site. Currently CBCT is the ideal choice, which has brought down implant failures by rendering accurate information **(Venkatesh and Venkatesh Elluru, 2017).**

The 3D visualization and evaluation of the structures of interest during the treatment planning phase allows for the analysis for the following parameters:

- Determination of the available bone height, width, and relative quality.
- Determination of the 3D topography of the alveolar ridge.
- Identification and localization of vital anatomical structures such as the inferior alveolar nerve, mental foramen, incisive nerve, maxillary sinus, ostium, and floor of the nasal cavity.
- Identification and 3D evaluation of possible incidental pathology.
- Fabrication of CBCT-derived implant surgical guides
- Communication of the diagnostic and treatment planning information to all members of the implant team.
- Evaluation of the prosthetic/restorative options through implant software applications. **(Benavides *et al*., 2012).**

The treatment planning software includes an "implant library" customized overlays corresponding to the shape and size of individual implant types. Within the planning software the clinician can virtually place the implant overlays, with consideration to individual anatomic and functional factors, implant parallelism, and the design of the prosthetic restoration. These include the local availability of bone volume, angulation relative to the adjacent teeth, and the proximity to vital structures. The virtually placed implants can be angulated and repositioned to simulate the final desired treatment plan. Virtual implant treatment planning allows the clinician to assess the need for bone augmentation and whether such augmentation could be accomplished at the time of implant placement. **(Mallya and Lam, 2018).**

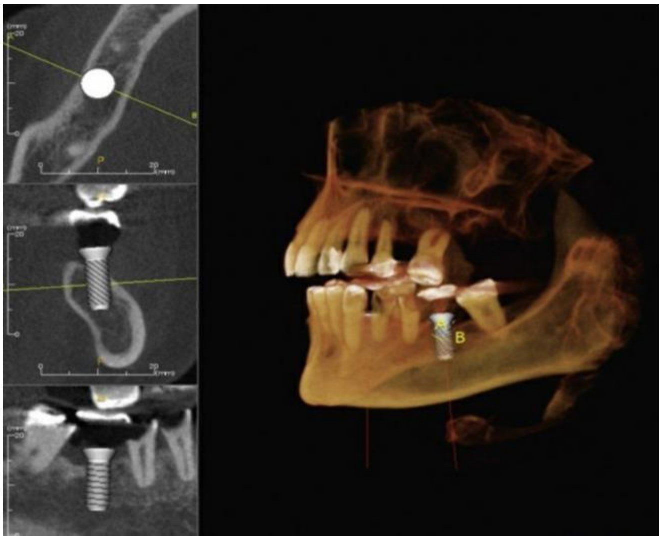

Figure 1.11. In Silico Implant planning. A virtual implant is positioned in the left mandibular first molar region. Axial, coronal, and sagittal sections through the virtual molar implant show exposure of the implant threads, indicating the need for bone augmentation **(Mallya and Lam, 2018).**

Active CBCT-aided implant surgery refers to the use CBCT data and surgical navigation systems to perform fully computer-guided implant placement. The accuracy of navigation systems has been tested in some studies, however, more research is need in this area **(Heiland *et al.*, 2008).**

1.8.4. Applications in TMJ disorders:

CBCT enables to examine the joint space and the true position of the condyle within the fossa, which is helpful in revealing likely dislocation of the joint disk. Additionally, CBCT enables to quantify the roof of the glenoid fossa and assists in locating the soft tissue around the TMJ, providing a practicable diagnosis and avoiding the necessity for Magnetic Resonance Imaging. These benefits drawn above have made CBCT the best imaging device for cases involving developmental anomalies of the condyle, trauma, fibro-osseous ankylosis, pain, dysfunction, and condylar cortical erosion, rheumatoid arthritis and cysts **(Honda *et al.*, 2001; Tsiklakis *et al.*, 2004; Honda *et al.*, 2004; Sakabe *et al.*, 2006; Kijima *et al.*, 2007).**

1.8.5. Applications in endodontics:

The published literature suggests that CBCT imaging is superior to 2D imaging in the description of periapical lesions, precisely demonstrating lesion juxtaposition to the maxillary sinus, sinus membrane involvement (Figure

1.12.), and lesion location relative to the mandibular canal. CBCT can be used to determine the number and morphology of roots and associated canals (both main and accessory), establish working lengths, and determine the type and degree of root angulation and as well provides true assessment of present root canal obturations. CBCT has been suggested for classifving the source of the lesion as endodontic or non-endodontic, which may influence treatment plan **(Nakata *et al.*, 2006; Cotton *et al.*, 2007; Tyndall and Rathore, 2008).**

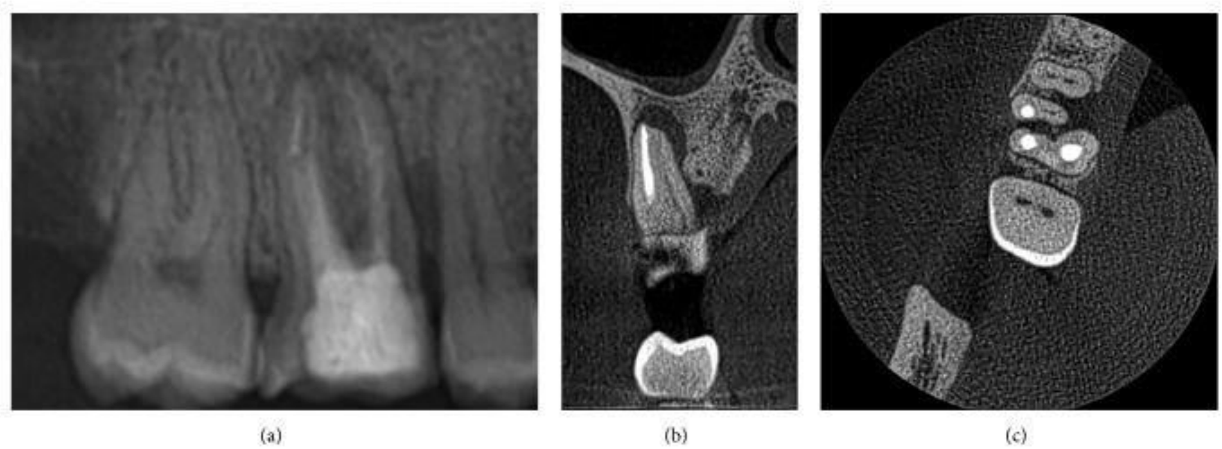

Figure 1.12.(a) Periapical X-ray: apex endodontic treatment and periapical radiolucency. (b) CBCT sagittal section: apex endodontic treatment MB, untreated MB2, and periapical radiolucency. (c) CBCT transversal section: untreated MB2. **(Giudice et al., 2018).**

1.9. Canine Impaction:

Canines, also known as cuspids, play fundamental roles in the aesthetics and function of patients. Canines are crucial for biting and tearing food, as well as directing the jaw into the proper orientation. The upper canines are the second most common teeth to become impacted following the wisdom teeth. The etiology of the impaction of canines includes genetic causes, lateral incisor anomalies and crowding **(Peck *et al.*, 1994; Vastardis, 2000).**

1.10. Etiology

The etiology of tooth impactions has long been related to an arch-length deficiency. This is valid for most impactions, but not for palatal impaction of the maxillary canine. The study showed that 85% of palatally impacted canines had sufficient space for eruption, whereas only 17% of labially impacted canines had sufficient space. Therefore, arch length discrepancy is thought to be a primary etiologic factor for labially impacted canine **(Jacoby, 1983).**

Localized

1. Tooth size-arch length discrepancies.
2. Failure of the primary canine root to resorb.
3. Prolonged retention or early loss of the primary canine.
4. Ankylosis of the permanent canine.
5. Cyst or neoplasm.
6. Dilaceration of the root.
7. Absence of the maxillary lateral incisor.
8. Variation in root size of the lateral incisor.
9. Variation in timing of lateral incisor root formation
10. Iatrogenic factors.

Systemic

1. Endocrine deficiencies.
2. Febrile diseases.
3. Irradiation.

Genetic

1. Hereditary.
2. Malposed tooth germ.

3. Presence of an alveolar cleft**. (Power *et al.*, 1993).**

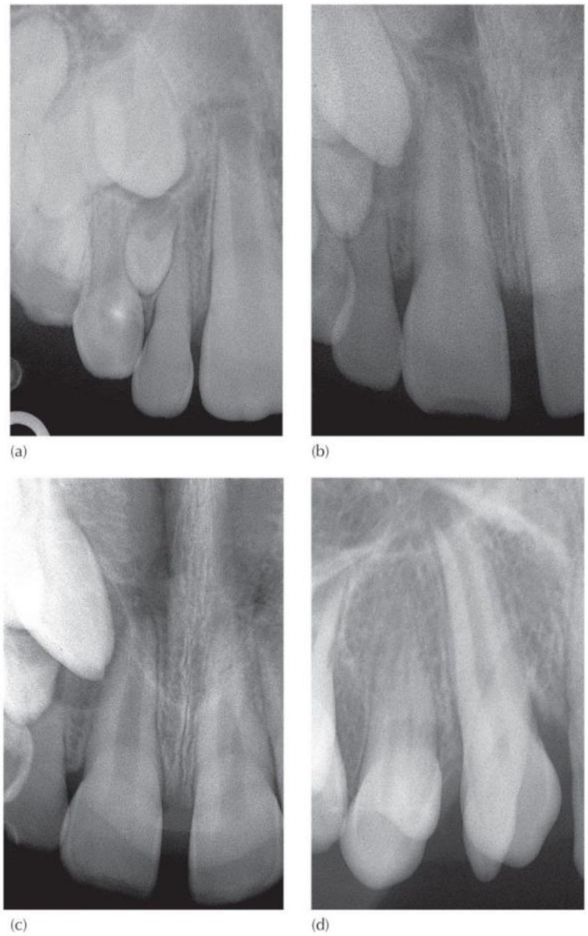

Figure 1.13. Serial radiographs showing the relationship of an unerupted canine to a late-developing and peg-shaped lateral incisor. (d) The two teeth have erupted and are superimposed on one another. At clinical examination the erupted canine was found to be on the palatal side of the lateral incisor **(Becker, 2012).**

1.11. Prevalence

Maxillary canine impaction occurs in approximately 2% of the population and is twice as common in females as it is in males. The incidence of canine impaction in the maxilla is more than twice that in the mandible. Of all patients who have impacted maxillary canines, 8% have bilateral impactions **(Bishara, 1992).**

Approximately one-third of impacted maxillary canines are located labially and two-thirds are located palatally **(Mitchell, 2007).**

1.12. Diagnosis of Canine Impaction

The diagnosis of canine impaction is based on both clinical and radiographic examinations.

1.12.1. Clinical Evaluation

It has been suggested that the following clinical signs might be indicative of canine impaction:

1. Delayed eruption of the permanent canine or prolonged retention of the deciduous canine beyond 14–15 years of age.

2. Absence of a normal labial canine bulge.

3. Presence of a palatal bulge, and

4. Delayed eruption, distal tipping, or migration (splaying) of the lateral incisor **(Bishara, 1992).**

1.12.2. Radiographic Evaluation

Although various radiographic exposures including occlusal films, panoramic views, and lateral cephalograms can help in evaluating the position of the canines, in most cases, periapical films are uniquely reliable for that purpose **(Ericson, 1987; Bishara, 1992).**

1.12.2.1 Periapical films

A single periapical film provides the clinician with a two-dimensional representation of the dentition. In other words, it would relate the canine to the neighboring teeth both mesiodistally and superoinferiorly. To evaluate the position of the canine buccolingually, a second periapical film should be obtained by one of the following methods.

A- Tube-shift technique or Clark's rule or (SLOB) rule

Parallax is the apparent displacement of an image relative to the image of a reference object and is caused by an actual change in the angulation of the x-ray beam. The change in angulation of the beam is caused by a change in the x-ray tube position. The reference object is normally the root of an adjacent tooth **(Clark, 1910).**

Two periapical films are taken of the same area, with the horizontal angulation of the cone changed when the second film is taken. If the object in question moves in the same direction as the cone, it is lingually positioned. If the object moves in the opposite direction, it is situated closer to the source of radiation and is therefore buccally located **(Ericson, 1987; Bishara, 1992).**

B- Buccal-object rule

If the vertical angulation of the cone is changed by approximately 20° in two successive periapical films, the buccal object will move in the direction opposite to the source of radiation. On the other hand, the lingual object will move in the same direction as the source of radiation. The basic principle of this technique deals with the foreshortening and elongation of the images of the films **(Ericson, 1987; Bishara, 1992).**

1.12.2.2 Occlusal films

Also help to determine the buccolingual position of the impacted canine in conjunction with the periapical films, provided that the image of the impacted canine is not superimposed on the other teeth **(Ericson, 1987; Bishara, 1992).**

If, in the image produced by this technique, the cusp of the canine is positioned in front of the ideal line connecting the apices of the lateral incisors, the position will be labial **(Goatz؛White, 1986).**

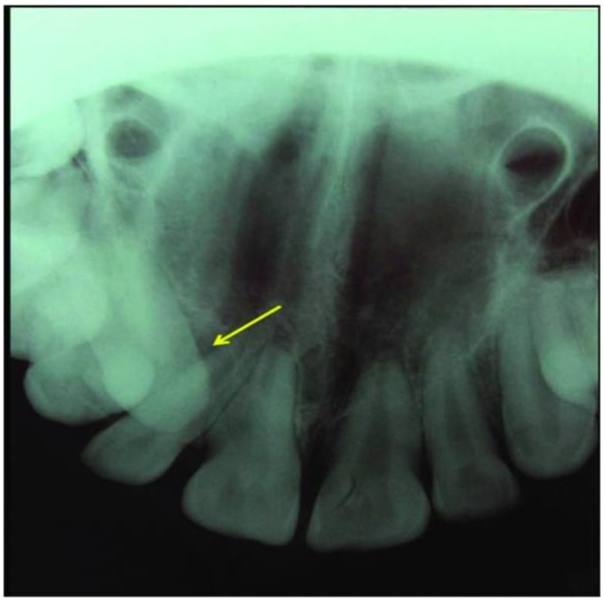

Figure 1.14. Occlusal radiograph showing labially impacted canine **(Kumar *et al.*, 2015).**

1.12.2.3 Extraoral films

A. Lateral cephalogram

If the dental age of the patient is between 8 and 9 y, the upper canines can easily be located by means of laterolateral teleradiography. This technique is useful in establishing the height of the impacted tooth and the anteroposterior position of the cuspid of the impacted canine with respect to the apices of the incisors. This may be indicative to establishing whether the impaction is in palatal or labial position. However, these data may be misleading in the case of bilateral canine impactions due to overlapping images of the two teeth. Evaluation of the impacted canine is carried out by tracing its axis and intersecting it with the perpendicular to Frankfurt's plane **(Orton *et al.*, 1995).**

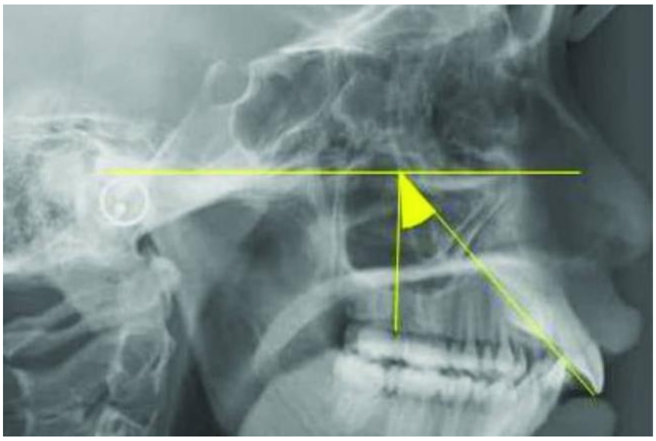

Figure 1.15. Canine position on Lateral Cephalogram **(Kumar *et al.*, 2015).**

B. Panoramic films

These are also used to localize impacted teeth in all three planes of space, as much the same as with two periapical films in the tube-shift method, with the understanding that the source of radiation comes from behind the patient; thus, the movements are reversed for position.

(Ericson and Kurol, 1988) defined number of sectors to denote different types of impaction:

i. Sector 1: if the cusp tip of the canine is between the interincisor median line and the long axis of the central incisor.

ii. Sector 2: if the peak of the cuspid of the canine is between the major axes of the lateral and central.

iii. Sector 3: if the peak of the cuspid of the canine is between the major axis of the lateral and the first premolar **(Ericson and Kurol, 1988).**

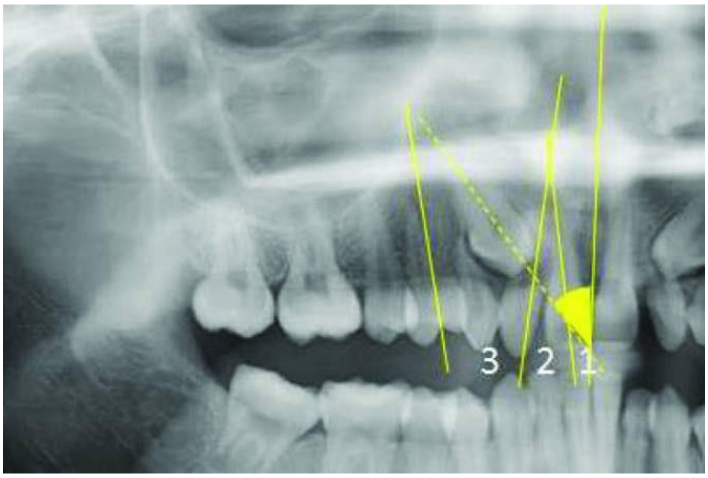

Figure 1.16. Sector Classification **(Ericson and Kurol, 1988).**

C. CT/CBCT:

Two-dimensional images provide inadequate information for the evaluation of impacted teeth. Cone beam computed tomography (CBCT) is an accurate and reliable method that supplies three-dimensional images of dentomaxillofacial structures without superimposition (figure 1.17. and 1.18) **(Dağsuyu *et al.*, 2018).**

CBCT can provide the accurate anatomy and position of the crown and root apex of the impacted canine and its orientation with the long axis **(Patil, 2017).**

CT provides excellent tissue contrast and eliminates blurring and overlapping of adjacent teeth. Despite its advantages, until now, the use of CT for location of impacted teeth and assessment of resorption has been restricted because of issues related to cost, risk/benefit, access, and expertise in reading the CT. Cone beam Computed Tomography was then introduced which reduces the exposure to radiation **(Manverna and Gracco, 2007).**

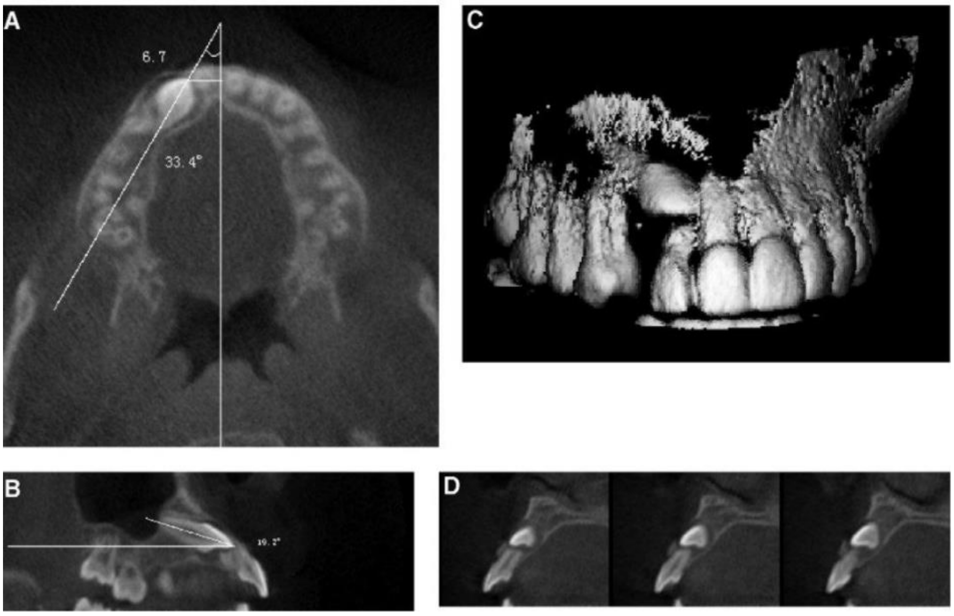

Figure 1.17.A, Axial view showed an impacted tooth 6 situated distally to tooth 8 and in contact with tooth 8, the horizontal angle of tooth 6 to midline was 33.4° and distance from cusp tip to midline was 6.7 mm. B, A transaxial view through the long axis of tooth 6 showed the vertical angle of tooth 6 to the occlusal plane (19.2°). C, Three-dimensional view showed the impacted canine situated mesio-labially to tooth 7. D, Sequential transaxial views showed that the cusp tip of tooth 6 located labially to the root apex of tooth 7. Note the severe resorption of the root **(Liu *et al.*, 2008).**

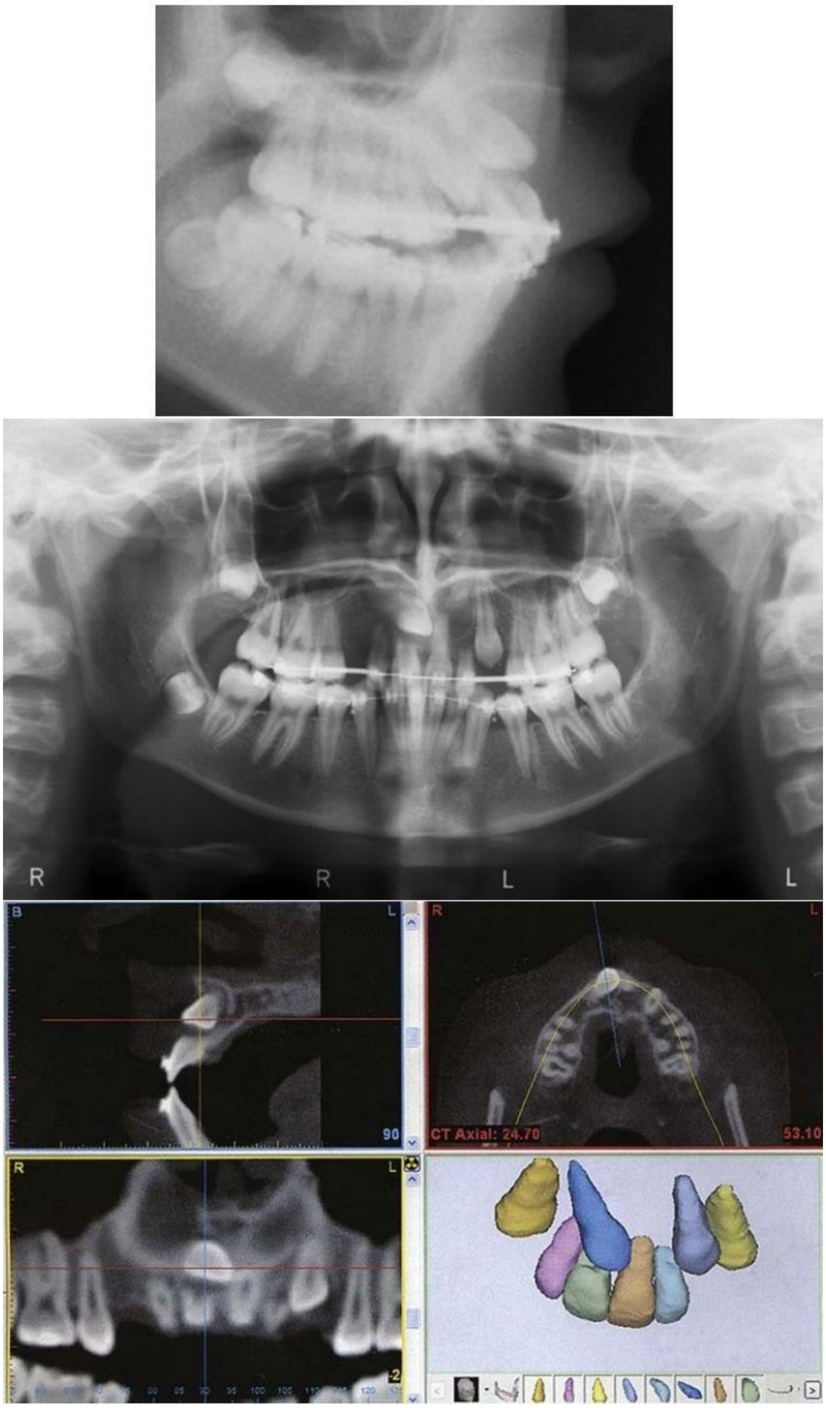

Figure 1.18. 3D radiographic imaging with CBCT can be a valuable adjunct to panoramic radiography and periapical localizing films in assessing impacted canines. For this patient, although the position of the impacted canine and the significant resorption of the root of the central incisor can be seen clearly from the panoramic image and from the lateral cephalogram, the 3D images add important information as to the path the canine would have to be moved to avoid further damage to the root of the central incisor if it is to be saved, and whether

it would be prudent to try to save the incisor or extract it. For difficult situations like this one, 3D imaging now is indicated **(Graber, 2017).**

1.13. Sequelae of Canine Impaction

1. Labial or lingual malpositioning of the impacted tooth.

2. Migration of the neighboring teeth and loss of arch length.

3. Internal resorption.

4. Dentigerous cyst formation (figure 1.19.).

5. External root resorption of the impacted tooth, as well as the neighboring teeth.

6. Infection particularly with partial eruption, and

7. Referred pain and combinations of the above sequelae **(Shafer *et al.,* 1963).**

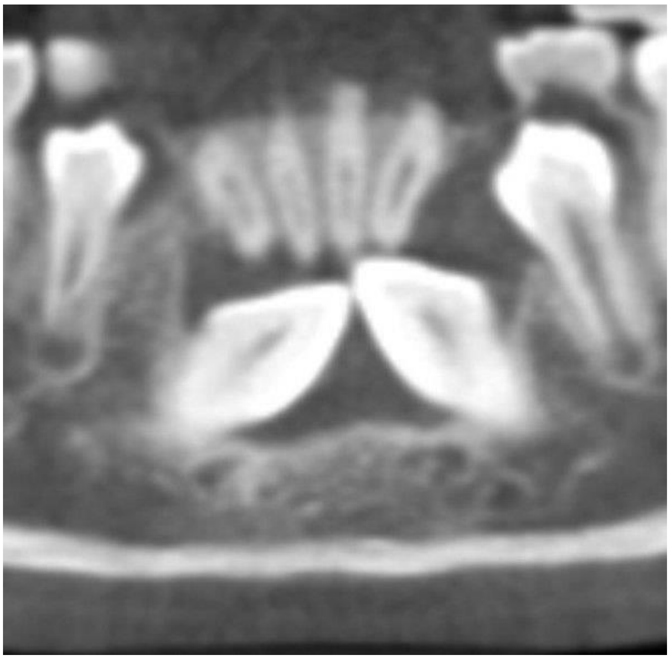

Figure 1.19. Reconstructed panoramic slice from cone-beam computed tomography data. A reconstructed panoramic slice of the anterior mandible shows a well-defined radiolucent area encompassing both impacted mandibular canine crowns with no separation. The border of the radiolucent area appears to be continuous with the cemento-enamel junction of both impacted permanent mandibular canines. **(Gonzalez *et al*., 2011)**

There are many studies concerned with CBCT use in impacted canine localization:

In 2008, Liu made a study about localization of impacted maxillary canines and observation of adjacent incisor resorption with CBCT, The study sample comprised 175 patients with impacted or ectopically erupting maxillary canines. These patients were referred for localization of these impacted teeth between July 2002 and August 2005, using cone beam CT (Verona, Italy). The results showed:

Of the 175 patients, 55 were male and 120 were female. Ages ranged from 10 to 59 years, with a mean age of 16.9 and a median of 14 years. One hundred forty patients presented with unilateral impacted canines and 35 with bilateral impactions.

		Age		*Impacted canines*		
	Number	*Range*	*Mean ± SD*	*Unilaterally*	*Bilaterally*	*Total*
Male	55	10-59	17.1 ± 7.8	43	12	67
Female	120	10-45	16.7 ± 6.5	97	23	143
Total	175	10-59	16.9 ± 6.9	140	35	210

Table 1.2. Distribution of maxillary canines according to sex and age in a sample of 175 patients.

Fifty-six of the 206 lateral incisors (4aplasia) were resorbed, resulting in a resorption rate of 27.2%. Forty-nine of the 209 central incisors (1 missing) were resorbed, giving a resorption rate of 23.4%

In total, the resorptions were mild in 49 cases, moderate in 33 cases, and severe in 23 cases. On the other hand, root resorption occurred only on the lateral incisors in 36 impacted canines, only on the central incisors in 29 impacted canines, and on both in 20 impacted canines. Therefore, resorption was associated with 85 (40.5%) of the 210 impacted canines.

In 2016, ALRWUILI et al., made a study to highlight the prevalence of impacted canines in orthodontic patients of Al-Qurayyat, Al-Jouf, Saudi Arabia. Two thousand two hundred and thirty nine patients visiting the Department of

Orthodontics, Qurayyat Specialized Dental Center, were included in this study. The study was conducted from year 2012 to 2015.

Total number of males were n= 836(37.34%) and females n= 1403(62.66%). The mean age of the patients was 22.92 ± 8.43. N=97/2239(4.33%) patients were diagnosed with impacted canines. Maxilla was the most common site of impaction, n=89/97(91.75%). Within maxilla, impacted canines were seen mostly as unilateral n=75(84.27%) and on left side n=59(66.3%).

Gender	Maxilla			Mandible		
	Left	Right	Bilateral	Left	Right	Bilateral
Male	16(27.1%)	5(31.25%)	4(28.57%)	1(33.3%)	2(40)	0(0%)
Female	43(72.9%)	11(68.75%)	10(71.43%)	2(66.7%)	3(60)	0(0%)
Total	59	16	14	3	5	0

In 2017, *Rahman V.F. and Fatah A.A.* made a study sample of 33 Iraqi subjects (17 males and 16 females) with an age range (13-27 years) attended to Al-Wasitti general hospital in Baghdad city-Oral and maxillofacial radiology department for Localization of maxillary impacted canine using cone beam computed tomography for assessment of angulation, distance from occlusal plane, alveolar width and proximity to adjacent teeth. The results showed that: Contact of impacted canine to the nearby teeth had a strong effect on their root resorption. Vertical or horizontal angulation measurement in axial view, was not possible for a number of cases. Comparison of the angulation measurement validity between axial and coronal views, had showed an obvious statistical difference in coronal view for vertical angulation, and in the axial view for horizontal angulation calculation.. Correlation of the canine localizations found in the study with the measurements, showed a significant statistical difference with age and vertical angulation (coronal view). Age or gender correlation with the measurements was non-significant statistically, except for age with vertical angulation (coronal view).

Impacted canine tooth localization was found in the study was: Labial - localization had the highest percentage (42%), while least (4%) for palatal localization crown and labial localization root, none was found as ectopic localization. 50 cases of maxillary impacted canines were found (22 in females and 28 in males), involved both bilateral and unilateral impactions.

In 2018, Patil SR et al made a retrospective study to determine the prevalence of impacted canines in a Saudi Arabian population using CBCT. A total of 439

CBCT scans of 241 male and 198 female subjects were analyzed in this study by two qualified observers to know the presence or absence of impacted canines and their distribution in terms of gender, jaw and side. The results showed that: Impacted canines were noted in 13 of 439 subjects with a prevalence of 3.03%, among which 7 (2.96%) were seen in males and 6 (3.12%) were seen in females. Out of these 13 impacted canines, 9 were observed in maxillary jaw, 3 in the right quadrant and 6 in the left quadrant. Four impacted canines were noted in mandibular jaw, 2 in right side and 2 in the left side.

Gender	**No. of patients examined**	**No. of patients without impacted canines**	**No. of patients with impacted canines**	**% of prevalence**
Male	241	234	7	2.90
Female	198	192	6	3.03
Total	439	15	13	2.96

Another study in 2018, Qadeer et al. made a retrospective study to evaluate prevalence and different patterns of mandibular impacted canines (MIC), using cone beam computed tomography (CBCT). CBCT records of 3469 patients were taken from two different radiological centers, the results showed that: 20 patients with MIC were identified with a mean age of 19 years. 85% of MIC were unilateral while 15% were bilateral. 15 % of MIC were transmigrated and were unilateral with a male to female ratio of 2:1.70% of MIC were labially placed. Bilateral impactions were found only in males. The prevalence of impacted mandibular canine was 0.57% while prevalence of transmigration was 0.09%. Unilateral and labial position of impacted canine was more predominant.

In 2022, Anastasia et al., made a systematic review and Meta-Analysis to assess scientific evidence published during the last decade, concerning the prevalence of lateral incisor RR caused by impacted maxillary canines, based only on cone-beam computed tomography (CBCT).The location of RR on this tooth, as well as the prevalence of RR on the other adjacent teeth, were additionally evaluated. Four databases were searched for articles published between January 2008 and June 2021. Predefined and piloted data collection forms were used to record the necessary information. A total number of 540 participants (176 males and 364 females) was derived from the included studies. RR of maxillary lateral incisors was common (50%). RR of mild severity was more common (62%), more frequently located in the middle (52%) and apical (42%) thirds of the root.

Chapter two

Conclusion:

CBCT has an effective role in accurate localization of impacted teeth especially canines, and help in making the final decision in the treatment plan either by orthodontic approach or by surgical approach. We can notice that impacted canine seems to be more in female than male in the majority of population, as well as the incisor resorption that happen at different levels.

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