Contents lists available at www.innovativejournal.in

INNOVATIVE JOURNAL OF MEDICAL AND HEALTH SCIENCE

Journal homepage: http://www.innovativejournal.in/index.php/ijmhs

ISSN No. 2277-4939

REVIEW

CONE BEAM COMPUTED TOMOGRAPHY – AN INSIGHT BEYOND EYESIGHT IN CLINICAL DENTISTRY

Guttikonda Venkateswara Rao[*1], S Anita Rao[2], P. Mallika Mahalakshmi[3], Soujanya . E[2]

[*1]*Department of Oral Pathology / Mamata Dental College, Khammam, Andhra Pradesh, India*

[2]*Department of Conservative Dentistry & Endodontics / Mamata Dental College, Khammam, Andhra Pradesh, India*

[3]*Department of Oral Medicine & Radiology / Mamata Dental College, Khammam, Andhra Pradesh, India*

ARTICLE INFO

Corresponding Author:
Dr. Guttikonda Venkateswara Rao,
Department of Oral Pathology /
Mamata Dental College, Khammam,
Andhra Pradesh,
India.

Keywords: CBCT, Field of view, Multiplanar reformation, voxel, Artifact.

ABSTRACT

Cone-beam CT is an exciting development in dental and maxillofacial imaging. It has provided astounding new images that continually contribute to the accuracy of diagnostic tasks of the maxillofacial region. It is gaining rapid acceptance in dentistry because it provides cross-sectional imaging that is often a valuable supplement to intraoral and panoramic radiographs. Multiplanar imaging is a fairly new concept in diagnostic imaging available with a number of contemporary imaging modalities. It has created a revolution in maxillofacial imaging, facilitating the transition of dental imaging from 2D to 3D images and expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures via third party applications software. The present article reviews the CBCT technology and its application in clinical practice.

INTRODUCTION

Imaging is an important adjunct to the clinical assessment of the dental patient. Though panoramic radiography in the 1960s through 1980s herald major progression dental radiology, providing clinicians with a single comprehensive image of the jaws and maxillofacial structures.

Cone-beam imaging, sometimes referred to as digital volume tomography, is one of the most exciting developments in dental and maxillofacial radiology and, owing to its versatility, will almost certainly become an increasingly popular form of imaging available in dental practice.

CBCT allows the creation in "real time" of images not only in the axial plane but also 2-dimensional images in the coronal, sagittal and even oblique or curved image planes — a process referred to as multiplanar reformation (MPR). [1]

HISTORY

CBCT was first adapted for potential clinical use in 1982 at the Mayo Clinic Biodynamics Research Laboratory. Initial interest focused primarily on applications in angiography in which soft-tissue resolution could be sacrificed in favor of high temporal and spatial-resolving capabilities. Since that time, several CBCT systems have been developed for use both in the interventional suite and for general applications in CT angiography. Exploration of CBCT technologies for use in radiation therapy guidance began in 1992, followed by integration of the first CBCT imaging system into the gantry of a linear accelerator in 1999. The first CBCT system became commercially available for oromaxillofacial imaging in 2001 (NewTom QR DVT 9000; Quantitative Radiology, Verona, Italy). Comparatively low dosing requirements and a relatively compact design have also led to intense interest in surgical planning and intra-operative CBCT applications, particularly in the head and neck but also in spinal, thoracic, abdominal, and orthopedic procedures. [2]

THE PRINCIPLE ON WHICH IT WORKS

CBCT image is accomplished by using a rotating gantry to which an x-ray source and detector are fixed. A divergent pyramidal or cone – shaped source of ionizing radiation is directed through the middle of the area of interest onto an area x-ray detector on the opposite side. The x-ray source and the detector rotate around a rotation fulcrum fixed within the center of the region of interest. During the rotation, multiple (from 150 to more than 600) sequential planar projection images of the field of view (FOV) are acquired in a complete or sometimes partial arc. The CBCT exposure incorporates the entire FOV, only one rotational sequence of the gantry is necessary to acquire enough data for the image reconstruction. [1]

TWO IMPORTANT FACTORS THAT MADE CBCT POSSIBLE

1. Development of compact high quality two – dimensional detector arrays
2. Refinement of approximate cone- beam algorithms

CONE BEAM CT IMAGE PRODUCTION

Current CBCT machines scan patients in three possible positions – sitting, standing, supine position .The four components of CBCT image production are:

1. ***Acquisition configuration*** – The geometric configuration and acquisition mechanism are simple. A single partial or full rotational scan from an x-ray source takes place while a reciprocating area detector moves synchronously with the scan around a fixed fulcrum within the patient's head.

X-ray generation during the scan rotation, each projection image is made by sequential single image capture of attenuated x-ray beams by the detector. The x-ray beam may be pulsed to coincide with the detector sampling, which means that actual exposure time is markedly less than scanning time. This technique reduces patient's radiation dose considerably.

Field of view –Is dependent on the detector size and shape, the beam projection geometry and the ability to collimate the beam. The shape of the scan volume can be either cylindrical or spherical. CBCT systems can be categorized according to the available FOV /selected scan volume height as follows:

1. Localized region : approximately 5cm/ less
2. Single arc :5cm to 7cm
3. Interarch:7cms to 10cms
4. Maxillofacial :10cm to 15cms
5. Craniofacial: greater than 15cms

The expansion of scan volume height has been accomplished by one unit (iCAT extended field of view model) by the software addition of two rotational scans to produce a single volume with a 22cm height. Another method of increasing the width of the FOV while using a smaller area detector, thereby reducing manufacturing costs is to offset the position of the detector , collimate the beam asymmetrically and scan only half the patient.

Scan factors – single exposures are made at certain degree intervals, providing individual 2D projection images as "basis", "frame" / raw images. The complete series of images is referred to as "projection data". The number of images comprising the projection data throughout the scan is determined by the frame rate (number of images acquired per second), the completeness of the trajectory arc, and the speed of the rotation. The number of projection scans comprising a single scan may be fixed (eg; New Tom) / variable (eg; i-CAT). More projection data provide more information to reconstruct the image, allow for greater spatial and contrast resolution, increase the signal to noise ratio, producing "smoother" images and reduce metallic artifacts. In accordance with the "as low as reasonable achievable "(ALARA) principle, the number of base images should be minimized to produce an image of diagnostic quality.

Frame rate and speed of rotation – Higher frame rates provide images with fewer and better image quality. The greater number of projections proportionately increases the amount of radiation a patient receives. Detector pixels must be sensitive enough to capture radiation adequate to register a high signal to noise output and to transmit the voltage to the analog and the digital converter, all within a short arc of exposure.

Completeness of Trajectory arc- CBCT imaging systems uses a complete circular trajectory / a scan arc of 360^0 to acquire projection data. This physical requirement is usually necessary to produce projection data adequate on for 3D reconstruction using the FDK algorithm. It is theoretically possible to reduce the completeness of the scanning trajectory and still reconstruct a volumetric data set. This reduces the scan time and is mechanically easier to perform. But the images produced by this method may have greater noise and suffer from reconstruction interpolation artifacts.

2*.* ***Image detection***- CBCT units can be divided into two groups based on detector type

1. An image intensifier tube / charge – coupled device (IIT/ CCD) combination

2. Flat panel imager

The IIT / CCD configuration comprises of an x-ray IIT coupled to a CCD by way of a fiber optic coupling. Flat panel imaging consists of detection of x-rays using an "indirect" detector based on a large area solid state sensor panel coupled to an x-ray scintillator layer. Flat panel detector arrays provide a greater dynamic range and greater performance than the IIT / CCD technology. Image intensifiers may create geometric distortions whereas flat panel detectors do not have this problem. This disadvantage could potentially reduce the measurement accuracy of CBCT units using this configuration. IIT / CCD systems also introduce additional artifacts.CBCT systems that use Flat-panel detectors also have limitations related to

1. Linearity of response to the radiation spectrum
2. Uniformity of response throughout the area of the detector
3. Bad pixels

The effects of these limitations on image quality are most noticeable at lower and higher exposures. To overcome this problem, detectors are linearized piecewise and exposures that cause non uniformity are identified and calibrated and pixel-by-pixel standard deviation assessment is used in non- uniformity. A reduction in image matrix size is desirable to increase spatial resolution and therefore provide greater image detail. The percentage area of the detector that actually registers information within an individual pixel is referred to as "fill factor". Although a pixel may have a nominal area, the fill factor may be of the order of 35%. Therefore smaller pixels capture fewer x-ray photons and results in more image noise. CBCT imaging using smaller matrix sizes require greater radiation and higher patient dose exposure. The resolution i.e., detail of CBCT imaging is determined by the individual volume elements / voxels produced from the volumetric data set. In CBCT imaging voxel dimensions depend on the pixel size on the area detector, unlike those in conventional CT which depend on slice thickness. The resolution of the area detector is sub millimeter (range-0.09mm to 0.4mm) which principally determines the size of the voxels. Therefore CBCT units provide voxel resolutions that are isotropic (equal in all dimensions).

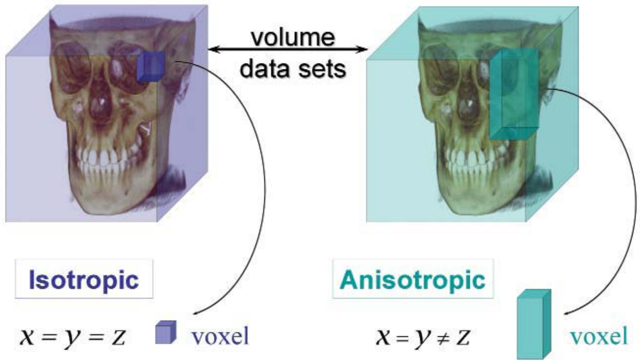


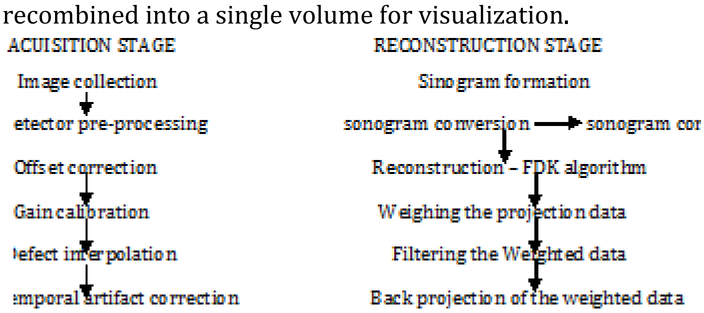
Figure 1: Isotropic Voxel Resolution

Gabriela Salatino Liedke et al has investigated the best voxel resolution in the detection of simulated external root resorption using CBCT and found that 0.3mm voxel size to be ideal because of is greater diagnostic accuracy with lower patient exposure to X-rays. [3]

3. ***Image reconstruction-*** Once the basic projection frames have been acquired, data must be processed to create the volumetric data set. This process is called "reconstruction". The number of projection frames may be from 100 to more than 600, each with more than one million pixels, with 12 to 16bits of data assigned to each pixel. Reconstruction times vary depending on the parameters (voxel size, FOV, number of projections), hardware (processing speed, data through output from acquisition to workstation computer) and soft ware used. Reconstruction process consists of two stages, each composed of numerous steps.

a. Acquisition stage –Because of the spatially varying physical properties of the photodiodes and the switching elements in the flat panel and because of variations in the x-ray sensitivity of the scintillator layer, raw images from CBCT detectors show spatial variations of dark image offset and pixel gain. the dark image offset (i.e., the detector output signal without any x-ray exposure), and its spatial variations are mainly caused by the dark current of the photodiodes. In addition to offset gain variations, even high quality detectors exhibit inherent pixel imperfections or a certain amount of defect pixels. To compensate these inhomogeneities, raw images require systemic offset and gain calibration and a correction of defect pixels. The sequence of the required calibration steps is referred to as "detector preprocessing" and the calibrations require the acquisition of additional image sequences.

b. Reconstruction stage – Once images are corrected, they must be related to each other and assembled. One method involves constructing a sinogram: a composite image relating each row of each projection image. The final step in reconstruction stage is processing the corrected sinograms. A reconstruction filter algorithm is applied to the sonogram and converts it into a complete 2D CT slice. The most widely used filtered back projection algorithm for cone beam-acquired volumetric data is the FDK algorithm. Once all the slices have been reconstructed, they can be recombined into a single volume for visualization.



4. ***Image display*** – The availability of CBCT technology provides with a great choice of image display formats. The volumetric data set is a compilation of all available voxels and for most CBCT devices; it is presented as secondary reconstructed images in three orthogonal planes usually at a thickness defaulted to the native resolution.[1]

ADVANTAGES OF CONE –BEAM CT

Rapid scan time – As CBCT acquires all projection images in a single rotation, scan time is comparable to panoramic radiography, which is desirable because artifact due to subject movement is reduced. Computer time for data set reconstruction is substantially longer, it depends on FOV, number of basis images acquired, resolution and reconstruction algorithm and may range approximately 1 minute to 20 mins.

Beam limitations- Collimation of the CBCT primary x-ray beam enables limitations of the x-ray radiation to the area of interest. An optimum FOV can be selected for each patient based on suspected disease presentation and region of interest. It provides dose savings by limiting the irradiated filed to fit the FOV.

Image accuracy- It produces images with submillimeter isotropic voxel resolution ranging from 0.4mm to as low as 0.076mm. Because of this characteristic subsequent secondary (axial, coronal and sagittal) and multiplanar reformation (MPR) images achieve a level of spatial resolution.

Reduced patient radiation dose- Effective doses vary for various full FOV CBCT devices ranging from 29 to 477 µSv, depending on the type and model of CBCT equipment and FOV selected. CBCT provides an equivalent patient radiation dose of 5 to 74 times that of a single film based panoramic x-ray / 3 to 48 days of background radiation. Patient positioning modifications and use of additional personal protection can substantially reduce the dose by up to 40%.

Multiplanar reformation: Because of the isotropic nature of the volumetric data sets, they can be sectioned non-orthogonally. Most software provides for various non axial 2D images referred to as MPR. MPR modes include oblique, curved planar reformation and serial transplanar reformation all of which can be used to highlight specific anatomic regions and diagnostic tasks. Because of the large number of component orthogonal images in each plane and difficulty in relating adjacent structures, two methods have been developed to visualize adjacent voxels.

Ray sum or ray casting: Any multiplanar image can be "thickened" by increasing the number of adjacent voxels included in the display, which creates an image slab that represents a specific volume of the patient, referred to as a "ray sum". Full thickness perpendicular ray sum images can be used to generate simulated projections such as lateral cephalometric images. These ray sum images are without magnification and are undistorted. This technique uses the entire volumetric data set, and interpretation suffers from the problems of "anatomic noise", the superimposition of multiple structures.

Three dimensional volume rendering

Volume rendering refers to techniques that allow the visualization of 3D data through integration of large volumes of adjacent voxels and selective display. Two specific techniques are available:

1. *Indirect Volume rendering*: It is a complex process; requiring selecting the intensity or density of the grayscale level of the voxels to be displayed within an entire data set

(called segmentation). This technique, technically demanding and computationally difficult, requiring specific software. It provides a volumetric surface reconstruction with depth.

2. *Direct Volume rendering*: It is a more simple process. The most common direct volume rendering is maximum intensity projection (MIP). MIP visualizations are achieved by evaluating each voxel value along an imaginary projection ray from the observer's eyes within a particular volume of interest and then representing only the highest value as the display value. Voxel intensities that are below an arbitrary threshold are eliminated.

LIMITATIONS OF CONE BEAM CT IMAGING

Current CBCT technology has limitations related to the "cone-beam" projection geometry, detector sensitivity and contrast resolution that produces images that lack the clarity and usefulness of conventional CT images.

The clarity of CBCT images is affected by artifacts, noise and poorer soft tissue contrast.

1. Artifacts

An artifact is any distortion or error in the image that is unrelated to the subject being studied.

Artifacts can be classified according to their cause:

A. *X-Ray beam artifacts*- CT image artifacts arise from the inherent polychromatic nature of the projection x-ray beam that results in what is known as "beam hardening" (i.e., its mean energy increases because lower energy photons are absorbed in preference to higher energy photons). This beam hardening results in two types of artifacts:

1. Distortion of metallic structures due to differential absorption, known as cupping artifact

2. Streaks and dark bands that can appear between two dense objects.

Because the CBCT x-ray beam is heterochromatic and has lower mean kilovolt energy compared with conventional CT, this artifact is more pronounce on CBCT images. It can be reduced by reducing the FOV to avoid scanning regions susceptible to beam hardening, which can be achieved by collimation, modification of patient positioning or separation of the dental arches.

B. *Patient related artifacts* -Patient motion can cause misregistration of data which appears as unsharpness in the reconstructed image. This unsharpness can be minimized by using a head restraint and as short a scan time as possible. The presence of dental restorations in the FOV can lead to severe streaking artifacts. They occur because of extreme beam hardening or photon starvation due to insufficient photons reaching the detector, resulting in horizontal streaks in the image and noisy projection reconstruction. It can be reduced by removing metallic objects such as jewellery before scanning commences.

C. *Scanner related artifacts*-They present as circular or ring shaped artifacts resulting from imperfections in scanner detection of poor calibration. Both these problems result in a consistent and repetitive reading at each angular position of the detector resulting in a circular artifact.

D. *Cone beam related artifacts*- The beam projection geometry of the CBCT and the image reconstruction method produce three types of cone beam related artifacts.

a. *Partial volume averaging*: It is a feature of conventional Fan and CBCT imaging. It occurs when selected voxel resolution of the scan is greater than the spatial or contrast resolution of the object to be imaged. In this case, the pixel is not representative of the tissue or boundary. However it becomes a weighted average of the different CT values. Boundaries in the resultant image may present with a "step" appearance or homogeneity of pixel intensity levels. Partial volume averaging artifacts occur in regions where surfaces are rapidly changing in the direction. Selection of the smallest acquisition voxel can reduce the presence of these effects.

b. *Under sampling*: It occurs when too few basis projections are provided for the reconstruction. A reduced data sample leads to misregistration and sharp edges and noisier images because of aliasing, where fine striations appear in the image. This effect may not degrade the image severely. However when resolution of fine detail is important, under sampling artifacts need to be avoided as far as possible by maintaining the number of basis projection images.

c. *Cone-beam effect*: It is a potential source of artifacts, especially in the peripheral portions of the scan volume. Because of the divergence of the x-ray beam as it rotates around the patient in a horizontal plane, projection data are collected by each detector pixel. The amount of data corresponds to the total amount of recorded attenuation along a specific beam projection angle as the scanner completes an arc. The total amount of information for peripheral structures is reduced because the outer row of detector pixels record less attenuation whereas more information is recorded for objects projected onto more central detector pixels, which results in image distortion, streaking artifacts and greater peripheral noise. This effect is minimized by incorporating various forms of cone-beam reconstruction. Clinically it can be reduced by positioning the regions of interest adjacent to the horizontal plane of the x-ray beam and collimation of the beam to an appropriate FOV.

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 engage in interactions by way of attenuation. These occur by Compton scattering producing scattered radiation. The scattered radiation is produced Omni- directionally and is recorded by pixels on the cone-beam area detector which does not reflect the actual attenuation of the object within a specific path of the x-ray beam. This additional recorded x-ray attenuation, reflecting non-linear attenuation is called noise. Because of the use of an area detector much of this non –linear attenuation is recorded and contributes to image degradation or noise. The scatter to primary ratios may be as large as 0.4 to 2 in CBCT.

Poor soft tissue contrast

Three factors limit the contrast resolution of CBCT. Scattered radiation contributes to increased image noise; it is also a significant factor in reducing the contrast of the cone-beam system. In addition divergence of the x-ray beam over the area detector causes a pronounced heel effect. This effect produces a large variation in or non-uniformity of the incident x-ray beam on the patient and resultant non uniformity in absorption with greater signal to noise ratio on the cathode side of the image relative to the anode side. Numerous inherent flat-panel detector-based artifacts affect its linearity or response to x-radiation. Increase in demand for better image quality in endodontic practice, there is growing need to measure and document image quality.

A study was carried by Sogur et al in which a comparison of the subjective quality of LCBCT, storage phosphor plate and

F-speed film images for the evaluation of the length and homogeneity of the root fillings. The results showed that image quality of storage phosphor films was subjectively as good as conventional film images and superior to LCBCT images for evaluating the homogeneity and length of root filling in single rooted teeth. [4]

APPLICATIONS OF CBCT IN DENTISTRY

CBCT imaging has focused on applications for dental implant placement, orthodontics, surgery, temporo mandibular joint imagining, caries diagnosis, detection and characterization of the bony aspects of periodontal disease, and endodontic applications.

Endodontics

1. In the diagnosis of periapical lesions due to pulpal inflammation [5]

a. CBCT eliminate the superimposition of anatomical structures. Eg: the roots of the maxillary posterior teeth and their periapical tissues can be visualized separately and in all three orthogonal planes without superimposition of the overlying zygomatic buttress, alveolar bone and adjacent roots.

b. CBCT enables periapical disease evidenced by radiolucent changes at the root apex to be detected earlier than on the conventional radiographs. CBCT scans have reported 62% more periapical radiolucent lesions detected on the individual roots of the manidbular and maxillary teeth when compared with two angled periapical radiographs. Early detection of periradicular radiolucent changes with CBCT should result in earlier identification and management of endodontic disease, this in turn should result in a better outcome from endodontic treatment as teeth could be treated sooner.

Marcelo Sampaio Moura et al in 2009 concluded that Apical periodontitis was detected more frequently when CBCT was used than by using periapical radiography. [6]

A study was performed using new periapical index based on CBCT. This was called as cone beam computed tomography periapical index (CBCTPAI). It was based on the criteria established from measurements corresponding to periapical radiolucency interpreted on CBCT scans. The size of the radiolucent images suggestive of periapical lesions were delimited and measured by using working tools of Planimap software on CBCT scan in 3 dimensions, bucco-palatal, mesio-distal and diagonal. The CBCTPAI was determined by the largest extension of the lesion. A 6 point (0-5) scoring system was used. For considering CBCT two additional variables such as expansion of cortical bone (E) and destruction of cortical bone (D) were included.

Score	Quantitative bone alterations in mineral structure
0	Intact periapical bone structure
1	Diameter of PA radiolucency > 0.5-1mm
2	Diameter of PA radiolucency > 1-2mm
3	Diameter of PA radiolucency > 2-4mm
4	Diameter of PA radiolucency > 4-8mm
5	Diameter of PA radiolucency > 8mm
Score (n) + E	Expansion of periapical cortical bone
Score (n) + D	Destruction of periapical cortical bone

The study concluded that A P detection was considerably higher with CBCT than with periapical radiography. The Periapical index proposed in this study offers as accurate diagnostic method for use with high resolution images, which can reduce the incidence of false-negative diagnosis, minimize observer interference. [7]

C. In situations where patients have poorly localized symptoms associated with an untreated or previously root filled tooth and clinical and periapical radiographic changes show no evidence of disease, CBCT may be indicated to detect the presence of previously undiagnosed periapical disease.

The grey scale value measurements of periapical lesions on CBCT images were able to differentiate solid (granulomas) from cystic / cavity type lesions. It may be clinically more accurate and more useful than biopsy. [5]

2. CBCT is also proved to be useful in planning periradicular endodontic surgery.

Three dimensional imaging allows the anatomical relationship of the root apices to important neighboring anatomical structures such as the inferior dental canal, mental foramen and maxillary sinus to be clearly identified. CBCT is useful to measure the distance between the cortical plate and the root apex, thickness of the cortical plate, cancellous bone, the cancellous bone pattern, fenestrations, the shape of the maxilla and mandible as well as the inclination of the roots of teeth .

Jay Simonton et al in 2009 have evaluated whether Age & Gender differences have any change in the position of the Inferior alveolar nerve which was important for pre-surgical evaluation using CBCT. They found out that females have a closer distance of the root apices to inferior alveolar nerve & decreased horizontal mandibular bone width than males. Also as age increased from 3rd – 6th decade of life, bone width significantly decreased regardless of the gender.

From the above results they have concluded that a CBCT scan will not stay constant throughout a person's lifetime, and a current CBCT might be recommended when appropriate before surgical treatment. [8]

3. 3DX micro-CT was used which is a limited Cone beam CT device which could clearly identify the exact position of the fractured instrument and its spatial relationship to the maxillary sinus. [9]

4. The lesions associated with apices near the sinus floor had a higher probability of being missed with periapical radiographs than lesions associated with apices far away or overlapping the sinus floor. Additional findings such as expansion of the lesion into the maxillary sinus, thickening of the sinus membrane, missed canals and presence of apico-marginal communications were more frequently detected with CBCT than with Peri apical radiography. The detection of apico-marginal communications was found to be an important factor associated with undetected vertical root fractures and is an important predictor for the success rate of apical surgery. [10]

5. CBCT is useful in diagnosis of dento-alveolar trauma because the exact nature and severity of alveolar and luxation injuries can be assessed from just one scan. It was used to detect horizontal root fractures. [5]

6. CBCT can detect Vertical root fracture (VRF) accurately.

Bassam Hassan et al in 2009 has done a study whether presence of Root canal filling can affect the accuracy of CBCT in detecting VRF and found that the presence of root filling did not have any effect on its accuracy. [11]

7. It is also used in the management of external cervical resorption lesions.

S. Patel et al in 2009 had found that CBCT was more reliable than intraoral radiography in the detection of root resorption lesions. [12] It was also presented that CBCT not only shows the exact location of the resorption but also reveals the true nature of the lesion. [5, 11]

8. In locating & identification of the root canals, potential accessory canals in teeth with suspected complex morphology based on conventional imaging.

Flares BarattoFilho et al in 2009 had compared in an Ex-vivo study, Operating microscope, Clinical & CBCT techniques to analyse the internal anatomy of Maxillary first molars and concluded that CBCT & Operating microscope were more accurate in locating & identifying root canals. [13]

9. Identification of root canal system anomalies and determination of root curvature.

10. Intra or postoperative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal and localization of perforations.[14]

Oral and maxillofacial surgery

- CBCT enables the analysis of jaw pathology in all dimensions, assessment of impacted teeth, supernumerary teeth and their relation to vital structures.
- It is also helpful in analyzing and assessing paranasal sinuses and obstructive sleep apnea.
- It is the technique of choice in mid-face fracture cases, orbital fracture assessment and management and for inter-operative visualization of the facial bones after fracture.
- Used in orthognathic surgery planning when facial orthornorphic surgery is indicated that requires detailed visualization of inter occlusal relationship in order to augment the 3-D virtual skull model with a detailed dental surface.
- Used in the pre operative volumetric assessment of cleft palate and to evaluate the lip and palate bony depressions.
- CBCT facilitates the visualization of soft tissue to allow for control of post-treatment aesthetics. [14]

Implantology

- Evaluation of normal anatomical structures, the detection of pathoses in proximity to proposed implant locations and available bone estimation in terms of quantity and quality.

Pawelzik et al, 2002, compared CBCT images with conventional panoramic images for diagnostic accuracy, prior to third molar surgery and concluded that CBCT images were free of magnification, superimposition of neighboring structures, and other problems inherent to panoramic radiology. This may result better assessment of implant sites pre-operatively.

- Assessment of Post treatment evaluation and success of bone grafts.
- On CBCT images, one can assess the course of the mandibular canal, such as the bifurcation and anterior loop, mandibular incisive canal and lingual foramen. The detection of the accessory mental foramen using CBCT images might reduce the rates of paralysis and hemorrhage in mental and cheek regions. [14]

Periodontology

- CBCT is used for a detailed morphologic mapping of bone including assessment of furcation involvement.
- Buccal and lingual defects which could not be identified on 2D images can be clearly demonstrated.
- Useful in assessment of Intra bony defects, dehiscence and fenestrations and outcomes of regenerative periodontal therapies.

The SEDENTEXCT guidelines conclude that "CBCT is not indicated as a routine method for imaging periodontal bone support" [14]

Orthodontics

- Used in the assessment facial growth, airway, disturbances of tooth eruption and cephalometric analysis.
- Safe insertion of mini screw implants (for anchorage) and proximity to vital structures can greatly aid complicated orthodontic case management.
- Complicated tooth movement predictability is greatly enhanced using CBCT to provide additional information. [14]
- Evaluation of impacted canines, other impacted teeth, root resorption, fractured roots, temporo mandibular joint degenerative changes, cleft lip and palate. [1]

Oral Medicicne & Radiology (Sialolithiasis)

- 3D CBCT images have high sensitivity and specificity for salivary calculus diagnoses than those obtained with other diagnostic methods. [14]

In summary, points to be considered:

1. CBCT and caries research results are mixed for proximal caries and few data exist for occlusal pit and fissure caries
2. CBCT imaging for caries should be limited to non restored teeth, we do not know the effect of beam hardening on producing artifacts and false- positives.
3. As for the periodontal disease, CBCT promises to be superior to 2D imaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height, this factor should be tempered with an awareness that restoration in the dentition may obscure views of the alveolar crest.
4. CBCT for endodontic purpose appears to be most promising use. Applications would include root fracture, apical lesions, canal identification, external and internal root resorption.
5. Assessment of impacted lower third molars in close proximity to the inferior alveolar nerve canal, evaluation of mid facial fractures, pre surgical assessment in orthognathic surgery and cleft cases and for detailed visualization of large bony pathologies.

With the appropriate use of CBCT technology and selected intraoral images, more information can be gain about dentoalveolar conditions and treatment with fewer risks and time occur benefiting both the patient and the dentist. CBCT imaging provides clinicians with sub-millimetre spatial resolution images of high diagnostic quality with relatively short scanning times (10–70 seconds) and a reported radiation dose equivalent to that needed for 4 to 15 panoramic radiographs.

Future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses. For now, CBCT imaging, like its medical counterpart, can be seen as a highly useful and, with some tasks, indispensable part of the dental imaging armamentarium.

REFERENCES

[1]. Dental clinics of north America v-52, 2008.
[2]. V.N.V.Madhav. [2011] Indian Journal of Dental Sciences.5: 10-15.
[3]. Liedke GS, da Silveira HE, da Silveira HL, Dutra V, de Figueiredo JA. [2009]Influence of voxel size in the diagnostic ability of cone beam tomography to

evaluate simulated external root resorption. J Endod.35:233-5.

[4]. Sogur. E, Baksi.B.G, Grondahl.H.G. [2007] Imaging of root canal fillings: a comparision of subjective image quality between limited cone beam Ct, storage phosphor and film radiography. Int Endod J.40:179-185.

[5]. Patel S, Dawood A, Ford TP, Whaites E. [2007] The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J.40:818-30.

[6]. Moura MS, Guedes OA, De Alencar AH, Azevedo BC, Estrela C. [2009] Influence of length of root canal obturation on apical periodontitis detected by periapical radiography and cone beam computed tomography. J Endod.35:805-9.

[7]. Estrela C, Bueno MR, Azevedo BC, Azevedo JR, Pecora JD. [2008) A new periapical index based on Cone beam computed tomography. J Endod.34:1325-31.

[8]. Simonton JD, Azevedo B, Schindler WG, Hargreaves KM. [2009] Age and gender related differences in the position of the inferior alveolar nerve by using Cone beam computed tomography. J Endod.35:944-9.

[9]. Tsurumachi T, Honda K. [2007] A new cone beam computed tomography system for use in endodontic surgery. Int Endod J. 40:224-32.

[10]. Kenneth.Low.M.T, Karl Dula, Walter Burgin, Thomas von arx.[2008] Comparison of periapical radiography and limited cone beam tomography in posterior maxillary teeth referred for apical surgery. J Endod.34:557-62.

[11]. Maini.A, Durning.P, Drage.N. [2008] Resorption: within or without? The benefit of cone beam computed tomography when diagnosing a case of an internal or external resorption defect. Br Dent J. 204:135-7.

[12]. Patel.S, Dawood.A, Wilson.R, Horner.K, Mannocci.F. [2009] The detection and management of root resorption lesions using intraoral radiography and cone beam computed tomography-an in vivo investigation. Int Endod J.42:831-8.

[13]. Baratto Filho F, Zaitter S, Haragushiku GA, de Campos EA, Abuabara A, Correr GM. [2009] Analysis of the internal anatomy of maxillary first molars by using different methods. J Endod. 35:337-42.

[14]. Vishal Dang. [2012] Cone Beam Computed Tomography (OCT): Prescription in dental practice today. Dental practice. 10: 16-18.