CBCT Scan

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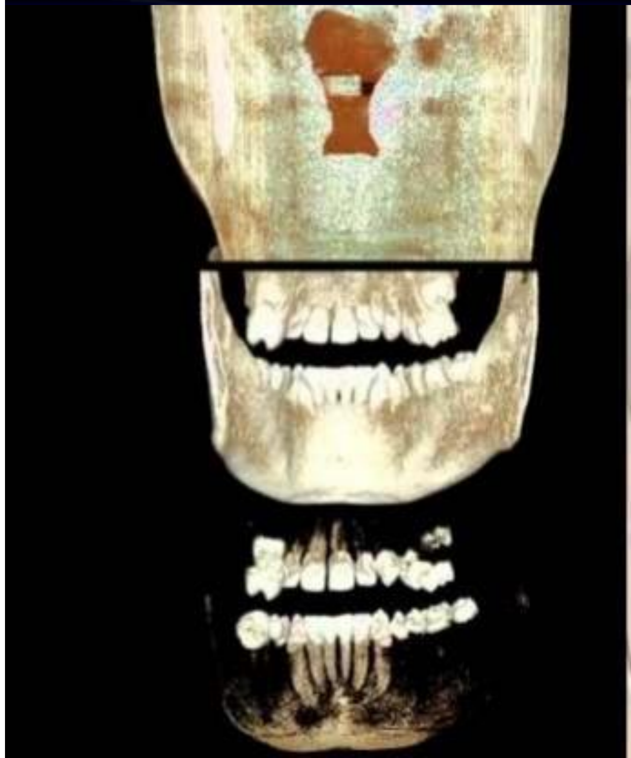
Introduction

- Radiology is important in the diagnostic assessment of the dental patient
- 3D diagnostic imaging of the jaws has been of interest since the introduction of CT as a clinical tool.
- Because of the relatively high cost, high dose, and availability limited to hospitals and medical radiology practices, use of this technology in dentistry has been limited.

What is CBCT?

- It is a technology used to take three-dimensional (3-D) images of your teeth, maxillary sinus, nerve pathways, and bone in the maxillofacial region with a single scan.



When CBCT?

Dental cone beam computed tomography is used when regular ttwo-dimensionaldental x-rays are not sufficient.

Why CBCT/CBVT

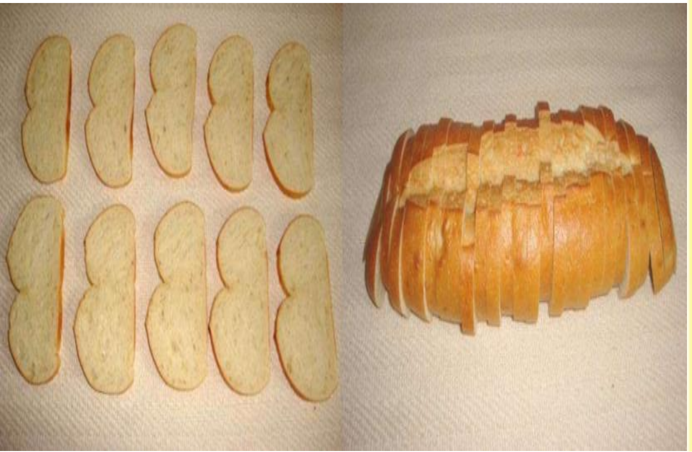
This may help with the diagnosis, treatment planning and evaluation of certain conditions.

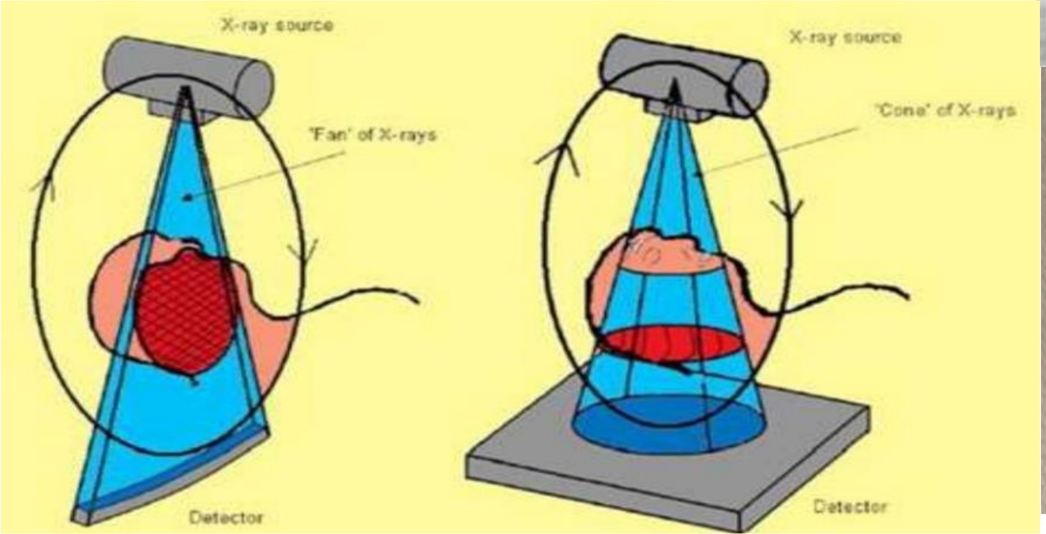
Medical CT:

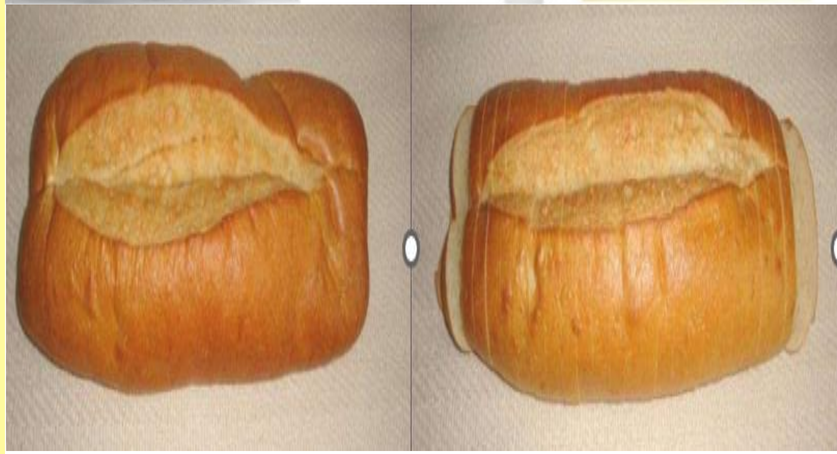
Slices are acquired then reconstructed to create the volume

CBCT:

The volume is acquired then slices are reconstructed from the volume







Imaging is an **important diagnostic** adjunct to **the clinical assessment of the dental patient** and **guidelines for the selection of appropriate radiographic procedures for patients suspected of having dental and maxillofacial diseases are available.**

Although combination of **plain X-ray transmission projections** and **panoramic radiography** can be adequate in a number of **clinical situations,** radiographic assessment may sometimes be facilitated by **multiplanar images including computed tomographs**.

Images of maxillofacial skeleton demonstrating 2 Dimensional view, haziness, overlapping, artefacts, distortion etc.

For most dental practitioners, the use of advanced imaging has been limited because of : **cost, Availability** and **radiation dose considerations**.

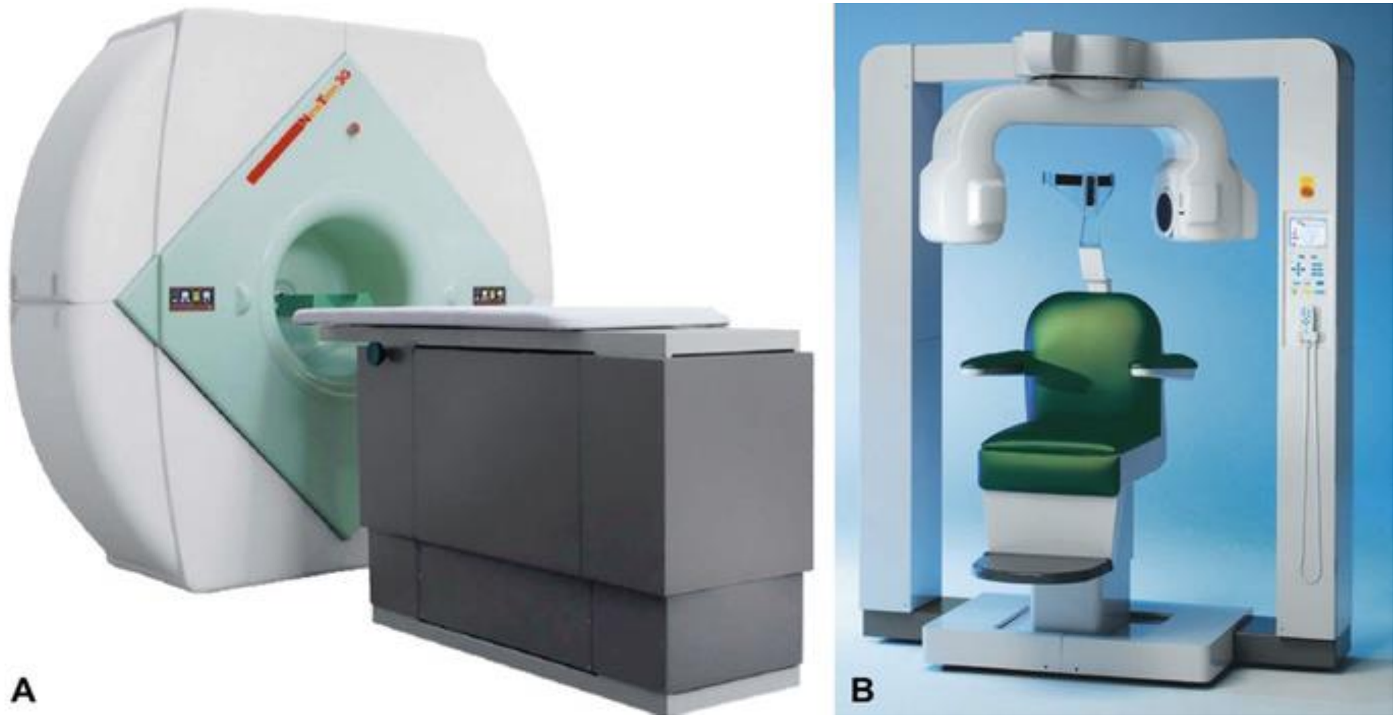
However, the introduction of **Cone Beam Computed Tomography [CBCT]** specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift from 2D to 3D approach to data acquisition and

provides opportunities for dental practitioners to request multiplanar imaging.

Cone beam computed tomographic (CBCT)

Cone beam computed tomographic (CBCT) imaging was originally developed for angiography in the early 1980s with the first dental and maxillofacial units introduced commercially in the late 1990s and early 2000s Unlike other extraoral dental imaging procedures, such as panoramic and cephalometric radiography, CBCT acquires data volumetrically providing three-dimensional (3D) radiographic imaging for the assessment of the dental and maxillofacial complex facilitating dental diagnosis. With expanding availability of third party application software capable of importing data in Digital Imaging and Communications in Medicine (DICOM) file format, the role of maxillofacial CBCT has now expanded to image guidance of operative and surgical procedures and, more recently, additive manufacturing of **biomodels** and **surgical guides**.

The First Commercially Available Maxillofacial Cone Beam Computed Tomography Units in the United States. (A) The NewTom 9000 DVT (QR srl, Verona,Italy) was a supine unit with a fixed spherical field of view (FOV) of 9 inches. (B) The 3D Accuitomo XYZ Slice View Tomograph (J. Morita Corp., Kyoto, Japan) was a unit in which the patient was seated and produced a small volume, cylindrical FOV with a high resolution.



There are three **main processes** in CBCT imaging: (1) image production, (2) visualization, and (3) interpretation

Principles of Cone Beam Computed

Tomographic Imaging

In all computed tomography (CT) techniques, a collimated x-ray source and adetector revolve around the patient The detector records photon attenuation by measuring the number of photons that exit the patient, registering this information at several hundred angles throug the rotational arc. These recordings constitute the “raw data” that is reconstructed by a computer algorithm to create a 3D data set composed of volumetric elements (**voxels**) from which images are derived. The basic

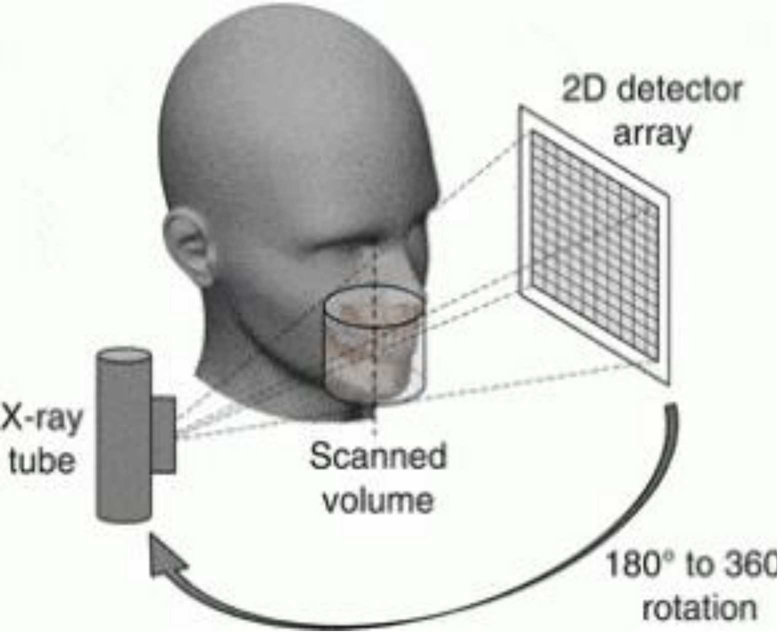
component of resultant grayscale images is the picture element (**pixel**) values. **The grayscale value or intensity of each pixel is related to the intensity of the photons incident on the detector**. Although providing similar images, **CBCT** and **multidetector computed tomography represents separate evolutionary arms of CT imaging**.

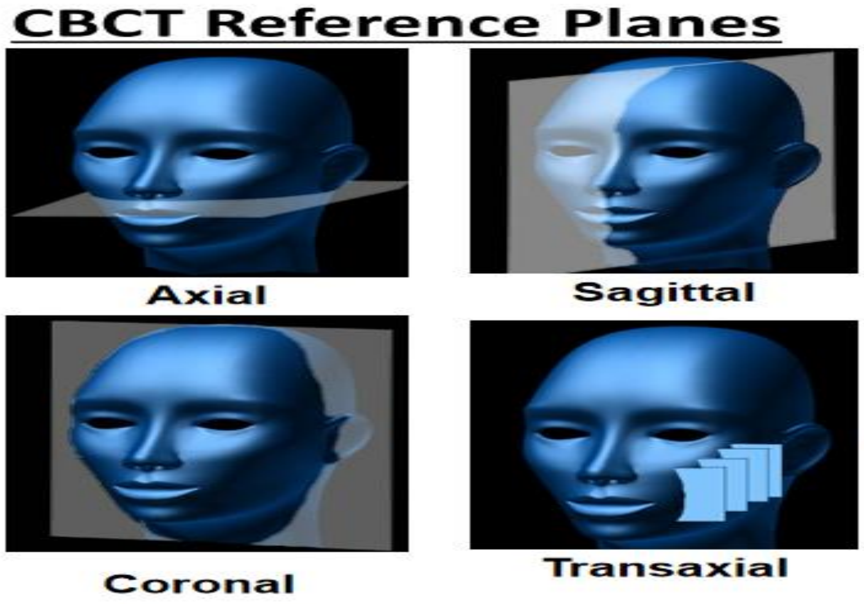
The geometric configuration and acquisition mechanics for the CBCT technique are theoretically simple .CBCT imaging is performed using a rotating gantry or C-arm supporting an x-ray source and reciprocating area detector. A divergent x-ray source, collimated as a cone or, more commonly, as a pyramid, is directed through the region of interest (ROI) within the maxillofacial

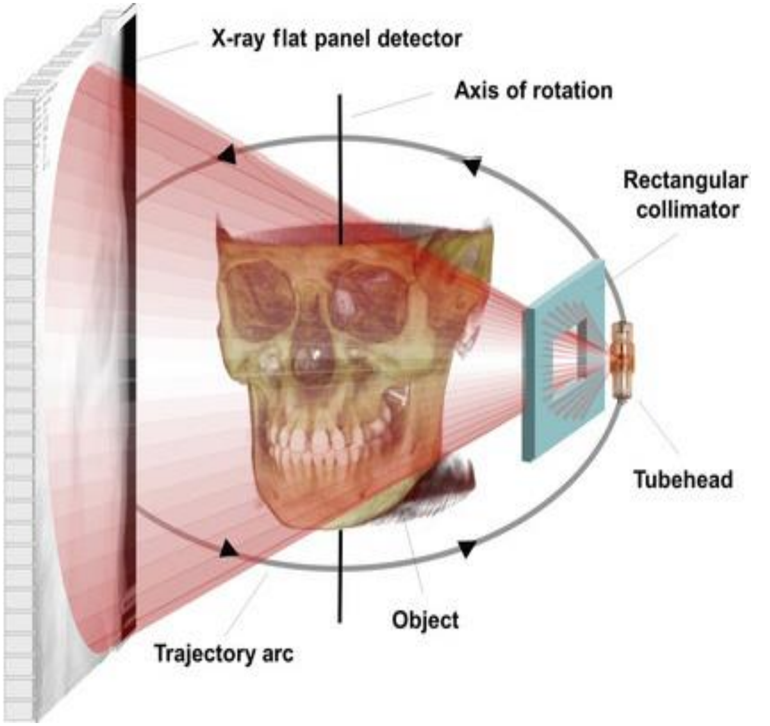
region, and the residual attenuated photons strike the detector on the opposite side. On activation, data are acquired from a series of sequential exposures as the gantry rotates around a fixed axis of rotation centered within the patient's ROI. The trajectory arc is ideally 360 degrees but can vary from 180 to 720 degrees. During the rotation, multiple sequential planar projection images are captured.These two-dimensional single-projection images constitute the raw primary data and are individually referred to as **basis**, **frame**, or **raw** images. Basis images appear similar to cephalometric radiographic images except that each is slightly offset from the next.

There are usually several hundred basis images with the complete series known as the **projection data**. Because CBCT exposureincorporates the entire ROI, only one rotational scan of the gantry is necessary to acquire enough data for volumetric image construction. Software programs incorporating sophisticated algorithms including filtered back projection are applied to these projection data to generate a **volumetric data set**—an **imagevolume** that can be used to **generate secondary reconstruction images in three orthogonal planes (axial, sagittal, and coronal)**.

Cone beam geometry captures volumetric data with scan times ranging from less than 5 to more than 30 seconds.







Cone Beam Imaging Geometry. A divergent x-ray beam created at the tube head is collimated in a circle or rectangle (this example) into a three-dimensional cone or pyramid, respectively. The x-ray projection is directed through the patient onto a detector (either solid-state flat panel detector [this example] or II/charge-coupled device). After a single two-dimensional projection is acquired by the detector, the x-ray source and detector rotate a small distance around a trajectory arc. At this second angular position, another basis projection image or frame is captured.

This sequence continues around the object for the entire 360 degrees (full trajectory) or along a reduced or partial trajectory capturing hundreds of individual images.

During the rotation, multiple sequential planar projection images are obtained while the x-ray source and detector move through an arc of 180 to 360 degrees.

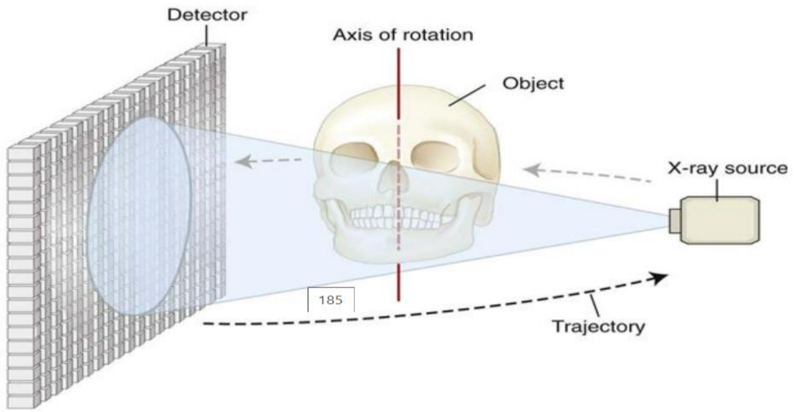
These single-projection images constitute the **raw primary data** and **are individually referred to as basis, frame**, or **raw images.** Basis images appear similar to cephalometric radiographic images except that each is slightly offset from the next. **There are usually several hundred two-dimensional basis images from which the image volume is calculated and constructed**.

The complete series of images is referred to as the **projection data**. Because CBCT exposure incorporates the entire ROI, only one rotational scan of the gantry of 180 to 360 degrees is necessary to acquire enough data for volumetric image construction.

Software programs incorporating sophisticated algorithms including filtered back projection are applied to these projection data to generate a volumetric data set that can be used to provide primary reconstruction images in three orthogonal planes (axial, sagittal, and coronal).

Cone-beam geometry captures volumetric data quickly, and this configuration affords significant cost savings compared with MDCT imaging because multiple patients can be imaged with CBCT imaging in the time taken for one patient to be imaged with MDCT imaging.

Cone-beam imaging geometry. A three-dimensional cone (this example) or pyramidal (if collimation is rectangular) divergent x-ray beam is directed through the patient onto a detector (either solid-state flat panel detector or II/charge-coupled device). After a single two-dimensional projection is acquired by the detector, the x-ray source and detector rotate a small distance around a trajectory arc. At this second angular position, another basis projection image or frame is captured. This sequence continues around the object for the entire 360 degrees (full trajectory) capturing hundreds of individual images or along a reduced or partial trajectory.



COMPONENT OF CBCT:

There are three major components to CBCT image production:

- X-ray generation
- X-ray detection
- Image reconstruction

The x-ray generation and detection specifications of currently available CBCT systems reflect proprietary variations in these parameters.

X-Ray Generation

Although CBCT imaging is technically simple in that only a single scan of the patient is made to acquire a projection data set, numerous clinically important parameters in x-ray generation affect both image quality and patient radiation dose

Patient Stabilization

Depending on the unit, CBCT examinations are made with the patient sitting, standing, or supine. Supine units are physically larger, have a greater physical **footprint**, and may not be accessible for patients with some physical disabilities. Standing units may not be able to be adjusted to a height low enough to accommodate wheelchair-bound patients. Although seated units are the most comfortable, they may not allow scanning of physically disabled or wheelchair-bound patients. With all systems, immobilization of the patient's head is more important than patient positioning because any head movement degrades the final image. Immobilization of the head is accomplished by using some combination of a chin cup, bite fork, or other head-restraint mechanism.

X-Ray Generator

Although **CBCT imaging is technically simple** in that **only a single scan of the patient is made to acquire a projection data set**, numerous clinically important parameters in x-ray generation affect both **image quality** and **patient radiation** dose.

During the scan rotation, each projection image set is made by sequential single image capture of the remnant attenuated x-ray beam by the area detector. X-ray generation may be continuous or pulsed to coincide with the detector activation.

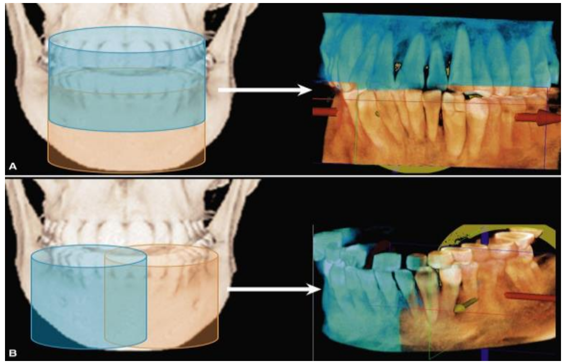
Preferably, the x-ray production should be pulsed to coincide with the detector sampling; this means that actual exposure time can be substantially less than scanning time. This technique considerably reduces patient radiation dose.The **ALARA (*A*s *L*ow *A*s *R*easonably *A*chievable)** principle of dose optimization necessitates that CBCT exposure factors should be adjusted on the basis of patient size and specific diagnostic task. This adjustment can be achieved by appropriate selection of tube current (milliamperes [mA]), tube voltage (kilovolt peak [kVp]), or both. In some cases, exposure time also can be adjusted to change scan time. **Faster scans produce volumetric data sets fromfewer basis images (see later section on scan factors)**. The variation in exposure parameters together with the presence of pulsed x-ray beam and size of the image field are the primary determinants of patient exposure

Scan Volume

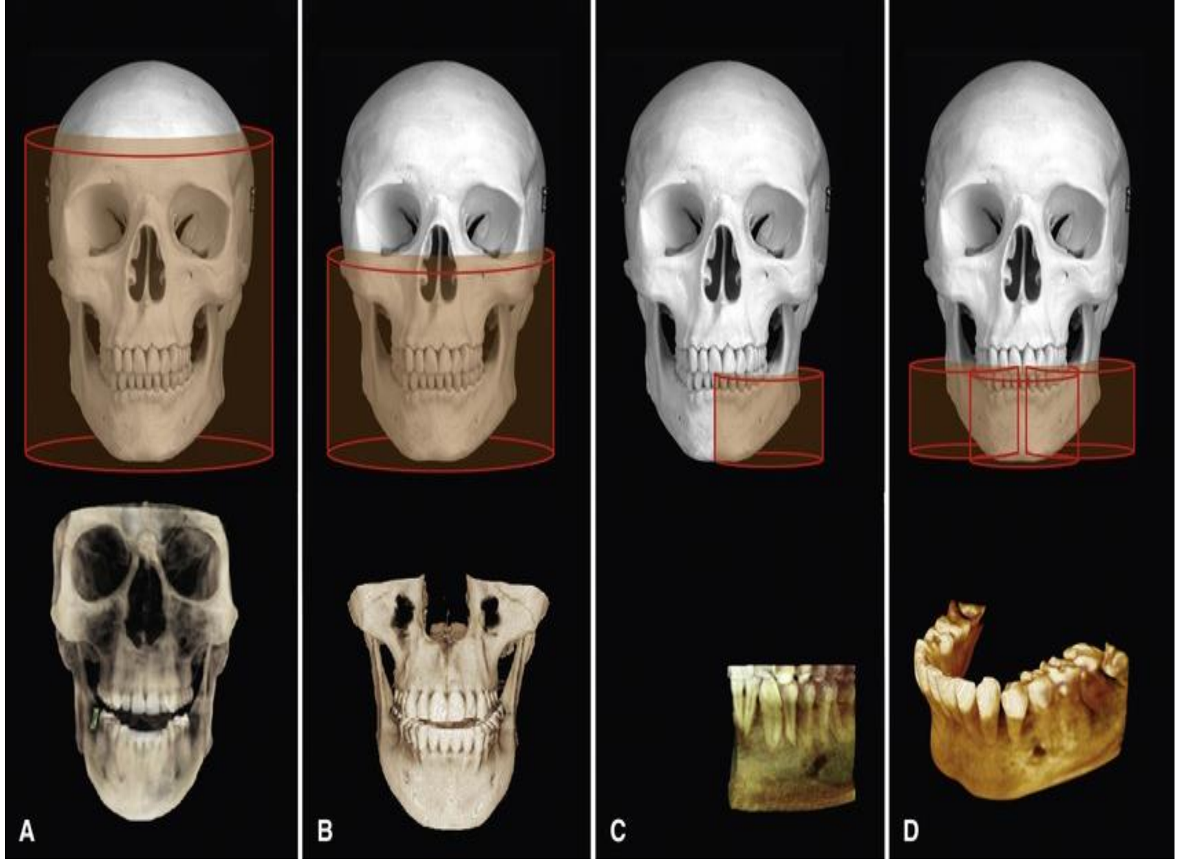
The dimensions of the **FOV** or **scan volume** primarily depend on the detector size and shape, the beam projection geometry, and the ability to collimate the beam. The shape of the scan volume can be either cylindrical or spherical.

Collimating the primary x-ray beam limits radiation exposure to the ROI. It is desirable to limit the field size to the smallest volume that images the ROI. This field size must be selected for each patient based on individual needs. This procedure reduces unnecessary exposure to the patient and produces the best images by minimizing scattered radiation, which degrades image quality. CBCTunits are classified according to the maximum FOV incorporated from the scan

Two approaches have been introduced to enable scanning of an ROI greater than the FOV of the detector. One method involves obtaining data from two or more separate scans and superimposing the overlapping regions of the CBCT data volumes using corresponding fiducial reference landmarks (referred to as either "bioimage registration" or "mosaicing"). Software is used to fuse adjacent image volumes ("stitching" or "blending") to create a larger volumetric data set either in the horizontal or in the vertical dimension The disadvantage of stitching overlapped regions is that such overlapped regions are imaged twice, resulting in double the radiation dose to such regions. A second method to increase the height or width of the FOV using a small area detector is to offset the position of the detector, collimate the beam asymmetrically, and scan only half the patient's ROI in each of the two offset scans



Increasing Field of View (FOV) by "Stitching" Volumetric Data Sets. Larger ROI can be acquired by small FOV cone beam computed tomography units by "stitching" adjacent limited area volumetric data sets. This process requires acquisition of separate scans *(left)*, registration of each volume by superimposition of fiducial landmarks, and fusion to provide a larger FOV *(right)*. Units may use this technique to increase either the vertical (A) or the horizontal (B) FOV. Shown here are adjacent *(orange and blue)* volumetric data sets (KODAK CS 9000 Carestream Dental, Atlanta, GA) stitched manually using proprietary software



Classification of Cone Beam Computed Tomography Units According to the Field of View (FOV). (A) Large FOV scans provide images of the entire craniofacial skeleton, enabling cephalometric analysis. (B) Medium FOV scans image the maxilla or mandible or both. (C) Focused or restricted FOV scans provide high-resolution images of limited regions. (D) Stitched scans from multiple focused FOV scans provide larger regions of interest to be imaged from superimposition of multiple scans

Scan Factors:

The number of images that constitute the projection data from the scan is determined by **the detector frame rate** (**number of images acquired per second**), the completeness of the **trajectory arc** (A **trajectory** or flight path is the path that an object with mass in motion follows through space as a function of time. In classical mechanics)(**180 to 360 degrees**), and the **rotation speed of the source** and **detector**.

The number of basis images of a **single scan** set may be **fixed** or **variable**.

Higher frame rates have both **desirable** and **undesirable effects**. **Higher frame rates increase the signal-to-noise ratio**, producing **images with less noise** and **reducing metallic artifacts**.

However, a **higher frame rate is associated with a longer scan time** and **higher patient radiation dose**. In addition, **more data are obtained**, and **primary reconstruction time is increased**.

In contrast, some "**quick-scan**" or "**fast-scan**" protocols use markedly **lower frame rates** with considerable reduction in **patient radiation dose**. However, the **image resolution** from these scans may **not be adequate for all diagnostic** tasks.

CBCT units are available, **providing fixed** or **variable rotation angles**. Most CBCT units have **fixed scan arcs.**

Fixed rotation angle units may be a full **360 degrees** or **partial trajectory arcs.**

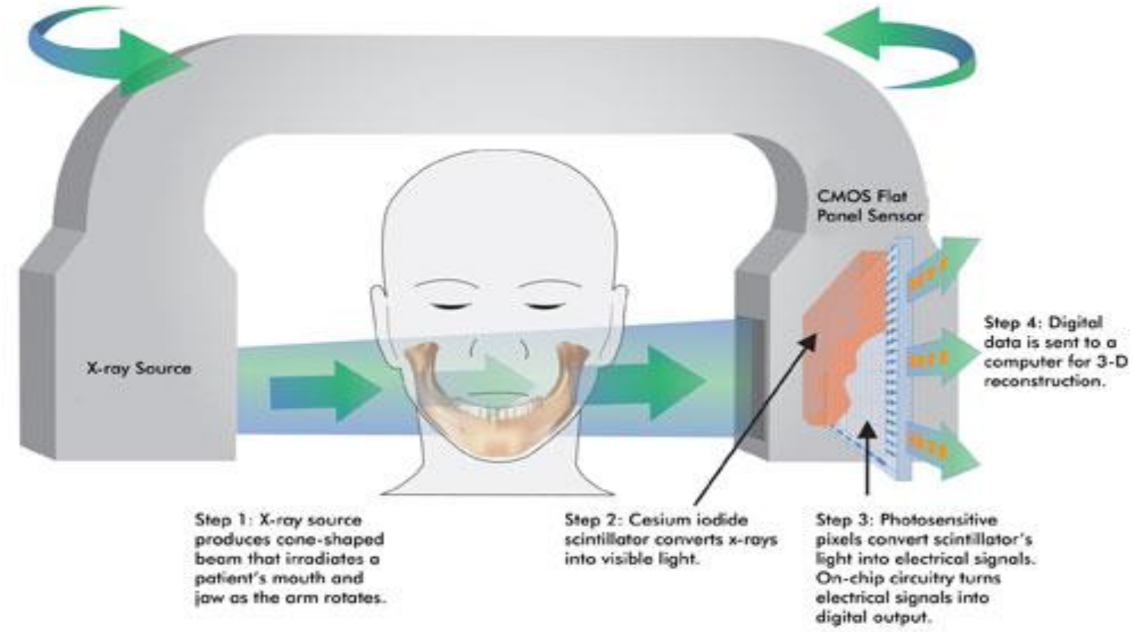
Ideally, **CBCT imaging** should be performed with a **full scan arc** to acquire adequate **projection data for volumetric software reconstruction**. However, many **CBCT units are based on panoramic platforms**, most **having scan arcs** less than **360 degrees**.

A limited scan arc potentially **reduces the scan time** and **patient radiation dose** and is **mechanically easier to perform**.

However, images produced by this method may have **greater noise** and **reconstruction interpolation artifacts**.
Units providing variable rotation angles usually provide **two options**: a **complete** or a **partial scan arc**.
It is desirable to reduce CBCT scan times to as short as possible to **reduce motion artifact resulting from patient movement**.
Patient movement **can be substantial** and **may be a limiting factor in image resolution.**
Decreased scanning times may be achieved by **increasing the detector frame rate**, **reducing the number of projections**, or **reducing the scan arc**. The first method provides **images of the highest quality**, whereas **the latter methods increase image noise**

Image Detectors:

Current CBCT units can be divided into **two groups** based on **detector type**: (1) image intensifier tube/charge-coupled device (II/CCD) combination or (2) flat panel detectors (FPDs). II/CCD units are usually larger and bulkier and result incircular basis image areas (spherical volumes) rather than rectangular ones (**cylindrical volu**mes) produced by FPDs. Most, but not all, **contemporary CBCT units use FPDs**. FPDs employ an "**indirect**" detector based on a large-area solidstate detector panel coupled to an x-ray scintillator layer .The most common flat panel configuration consists of a **cesium iodide scintillator** applied to a thin film transistor made of amorphous silicon. More recently, large complementary **metal oxide semiconductor technology arrays have also been used.**



Voxel Size:

The spatial resolution—and therefore detail of a CBCT image—**is determined by the dimensions of individual voxels produced in formatting the volumetric data set**.

CBCT units in general provide **voxel resolutions that are isotropic**—**equal in all three dimensions**.

The principal determinants of nominal voxel size in a CBCT image are the matrix and pixel size of the detector. Detectors with smaller pixels capture fewer x-ray photons per voxel and result in more image noise.

Consequently, CBCT imaging using higher resolutions may be designed to use higher dosages to achieve a reasonable signal-to-noise ratio for improved diagnostic image quality.

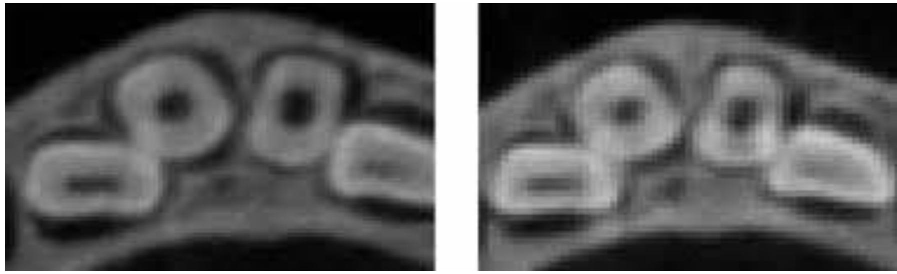
Both the **focal spot size** and the **geometric configuration of the x-ray source are important to determine the degree of geometric unsharpness**, a limiting factor in **spatial resolution**.

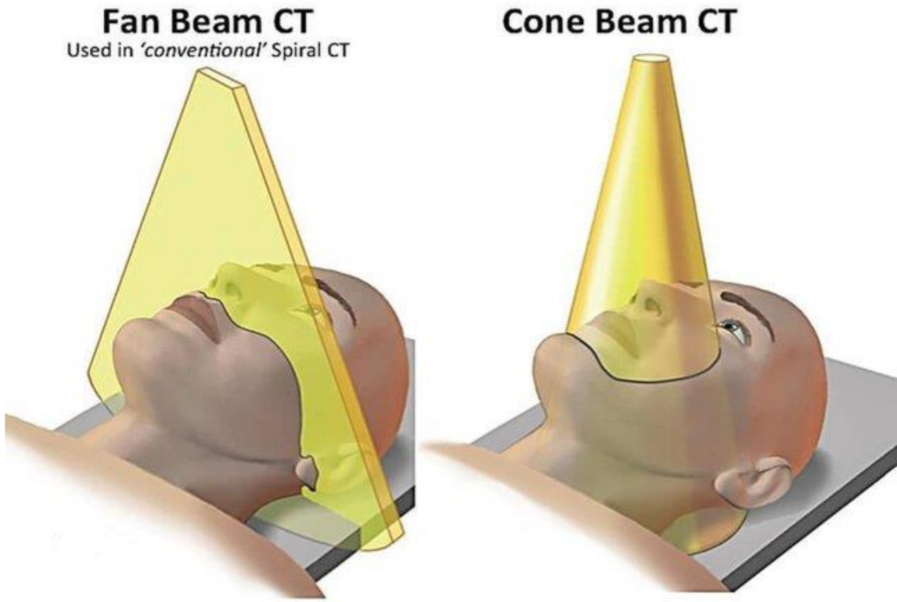
The cost of x-ray tubes—and therefore of the CBCT unit—increases substantially with **small focal spot size tubes**.

Reducing the **object-to detector distance** and **increasing source-to-object distance also minimizes geometric unsharpness**.

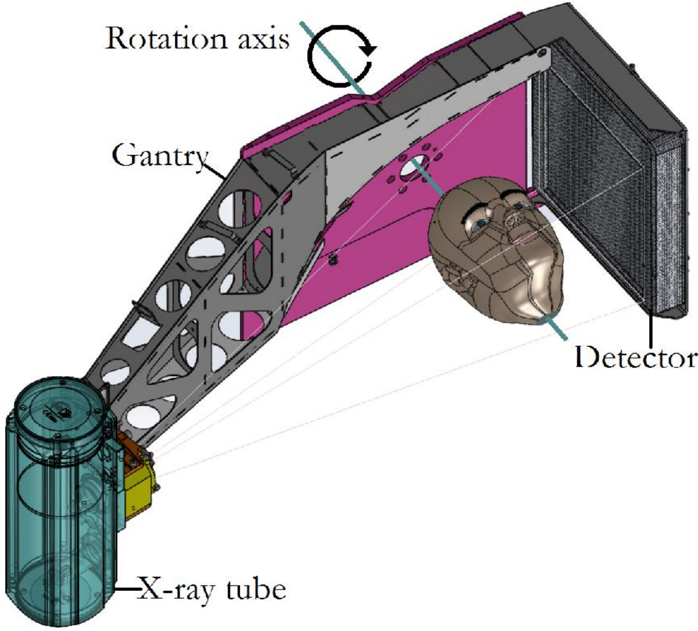
In maxillofacial CBCT imaging, the detector position is limited because it must be located **far enough from the patient's head** so that it freely rotates unobstructed by the patient's shoulders.

Voxel size determines the claritiy of images (Voxel = Volume + Pixel)





Limitations also exist in extending the source-to-object distance because this increases the size of the CBCT unit. However, **reducing source-to-object distance produces a magnified projected image on the detector, increasing potential spatial resolution**. Additional factors influencing **image resolution** include motion of the patient's head during the exposure, the type of **scintillator** used in the detector, and **the image reconstruction algorithms applied**



Scintillator Detector

Grayscale

The ability of **CBCT imaging** to display differences in photon attenuation is related to the ability of the **detector to reveal subtle contrast differences**. This parameter is called the **bit depth** of the system and determines the number of shades of gray available to display the attenuation. All currently available CBCT units use detectors capable of **recording grayscale**
differences of 12 bits or greater. A 12-bit detector provides 212 or 4096 shades to display contrast. **A 16- bit detector provides 216 or 65,536 shades of gray**. Although higher bit-depth images in CBCT imaging are possible, this added information comes at the
expense of increased computational time and substantially larger file sizes.

Reconstruction:

Although a single acquisition rotation may take less than **20 seconds**, it produces **100 to more than 600 individual projection frames**, each with more than **1million pixels** with **12 to 16 bits of data assigned to each pixel**.

These data are **processed** to **create a volumetric data set composed of cuboidal volume elements (voxels)** by a sequence of software algorithms in a process called **primary reconstruction**.

Subsequently, visual orthogonal (i.e., perpendicular) images are **reformatted by sectioning the volumetric data** set, referred to as **secondary reconstruction**.

The reconstruction of these data is computationally complex.

To facilitate data handling, data may be acquired by one computer (**acquisition computer**) and **transferred by an Ethernet connection to a processing computer (workstation**).

In contrast to **conventional CT imaging**, CBCT data reconstruction is performed by **personal compute**r–based, rather than **workstation**, **platforms**. The reconstruction process consists of **two stage**s, each **comprising numerous steps**

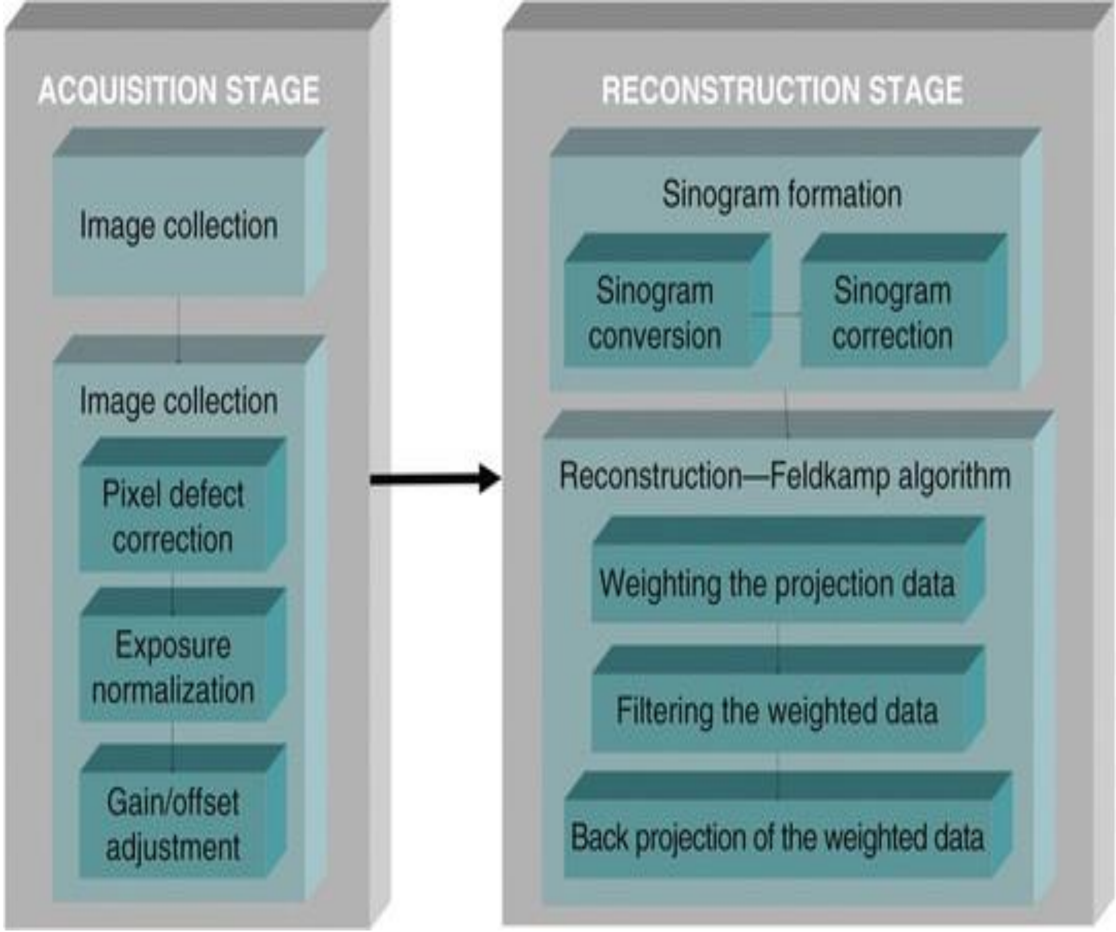


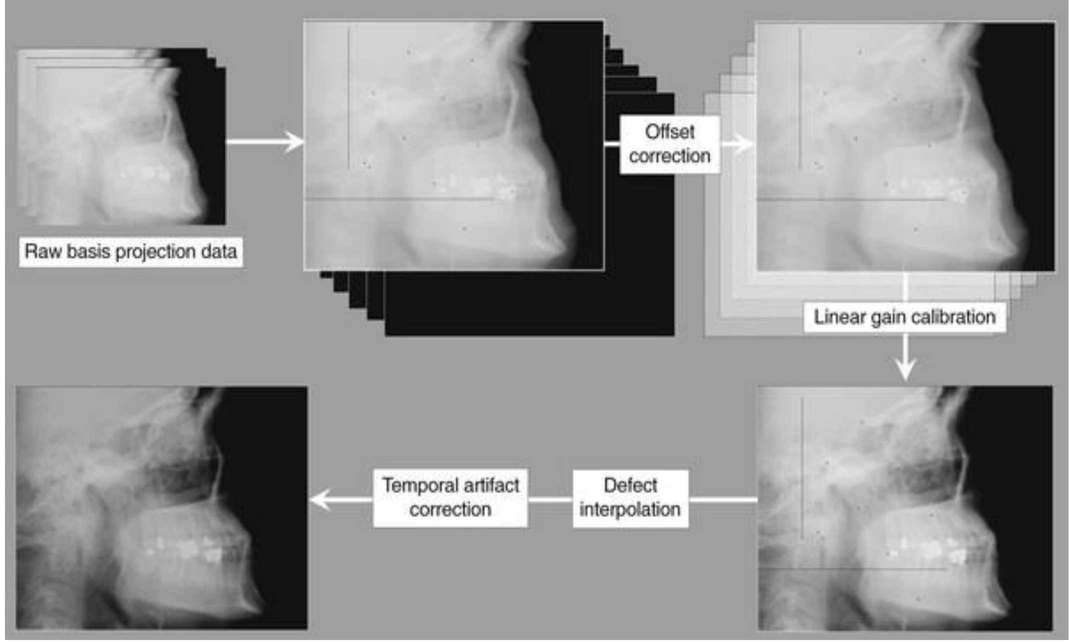
Image Acquisition and Reconstruction. The acquisition stage involves acquisition of individual basis projections and subsequent modification of these images to correct for inconsistencies. Image correction is sequential and consists of the removal of signal voids from individual or linear pixel defects, image normalization by histogram equalization so that a full range of voxel intensity values are used, and removal of inherent electronic detector artifacts. After correction, images undergo reconstruction, which includes converting the corrected basis projection images into sinograms and application of the Feldkamp reconstruction to the corrected filters to the image and use of back-projection techniques to reconstitute the image.

1. Preprocessing stage :

The preprocessing stage is performed at the acquisition computer. **After the multiple planar projection images are acquired**, these images must be corrected for **inherent pixel imperfections**, variations in sensitivity across the detector, and uneven exposure. **Depending on the CBCT unit**, image calibration may be **required routinely** to remove **these defects**.

2. Reconstruction stage.

The remaining data-processing steps are performed on the reconstruction computer. The corrected images are converted into a special representation called a **sinogram**, a composite image developed from multiple projection images. This process of generating a **sinogram** is referred to as the **Radon transformation**. The final image is reconstructed from the **sinogram** with a filtered back-projection algorithm for volumetric data acquired by CBCT imaging; the most widely used algorithm is the Feldkamp algorithm. This process is referred to as **inverse Radon transformation**. When all slices have been reconstructed, they are combined into a single volume forvisualization.



Cone Beam Computed Tomography (CBCT) Detector Preprocessing. The first step of CBCT detector preprocessing is offset correction. This is accomplished by pixel-wise subtraction of an individual offset value computed by averaging over a series of up to 30 dark images. **The second step is the linear gain calibration**, consisting of dividing each pixel by its individual gain factor. The gain factors are obtained by averaging a sequence with up to 30 images of homogeneous exposures without any object between x-ray source and detector. The gain sequence is first offset corrected with its own sequence of dark images.

The next procedure is the defect interpolation. Each pixel that shows unusual behavior, either in the gain image or in the average dark sequence, is marked in a defect map. The gray values of pixels classified as defective in this way are computed by linear interpolation along the least gradient descent.

For flat panel detectors, there is usually an additional procedure to correct for temporal artifacts. These arise in such detectors because both the scintillator and the photodiodes exhibit **residual signals**

Reconstruction times vary depending on the **acquisition parameters** (voxel size, size of the image field, and number of projections), hardware (processing speed, data throughput from acquisition to reconstruction computer), and software (reconstruction algorithms) used.

Reconstruction should be accomplished in an **acceptable time** (<5 minutes) to facilitate clinical workflow

Benefits/Risks of CBCT:

X-ray imaging, including dental CBCT, provides a fast, non-invasive way of answering a number of clinical questions. Dental CBCT images provide three-dimensional (3-D) information, **rather than the two-dimensional (2-D) information provided by a conventional X-ray image**. This may help with the diagnosis, treatment planning and evaluation of certain conditions.

Although the radiation doses from dental CBCT exams are generally lower than other CT exams, dental CBCT exams typically deliver more radiation than conventional dental X-ray exams.

Concerns about **radiation exposure** are greater for younger patients because they are more s**ensitive to radiation** (i.e., estimates of their lifetime risk for cancer incidence and mortality per unit dose of ionizing radiation are **higher**) and they **have a longer lifetime for ill effects to develop.**

Strength and limitations of the CBCT

Advantages of CBCT: (Strength)

•Low radiation (much less than traditional CT scan)
•Convenient and painless for patients
•Aid in the diagnostics, development of treatment plan, and procedures
•Assess risk
•Better analyze position and orientation of surrounding structures (sinuses, roots, and nerves)
•Cost effective
•Safe for patients of all ages

Disadvantages (Limitations) of CBCT

Although CBCT has made a speedy ingress into the field of dentistry, currently it is not devoid of drawbacks, which may be related to the ‘‘cone-beam’’ projection geometry, detector sensitivity, and contrast resolution. The clarity of CBCT images is affected by artifacts, noise, and poor soft tissue contrast.

An artifact is any distortion or error in the image that is unrelated to the subject being studied. This **impairs CBCT image quality** and **limit adequate visualization of structures in the dento-alveolar region**.

Artifacts can be due to **beam hardening (results in cupping artifact and streaks and dark bands**), **Patient-related artifacts (Patient motion resulting in unsharpness of the reconstructed image),** Scanner-related artifacts (circular or ringshaped) and cone beam–related artifacts (partial volume averaging, **undersampling, and cone-beam effect**) .

Image noise is due to **large volume being irradiated during CBCT scanning** resulting in heavy interactions with tissues producing scattered radiation, which in turn leads to nonlinear attenuation by the detectors. This additional x-ray detection is **called noise** and **contributes to image degradation**

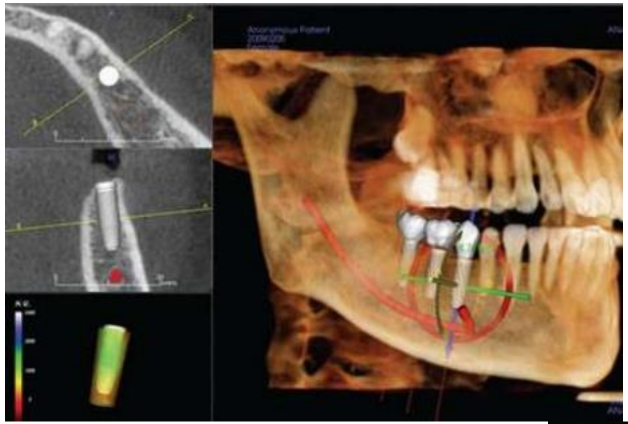
Poor soft tissue contrast: CBCT units have noticeably less soft tissue contrast than conventional CT machines.**Three factors limit the contrast resolution of CBCT**, which include **increased image noise**, the **divergence of the x-ray beam** and numerous inherent flat-panel detector-based artifacts

EPX-IMPLA

Use in dentistry

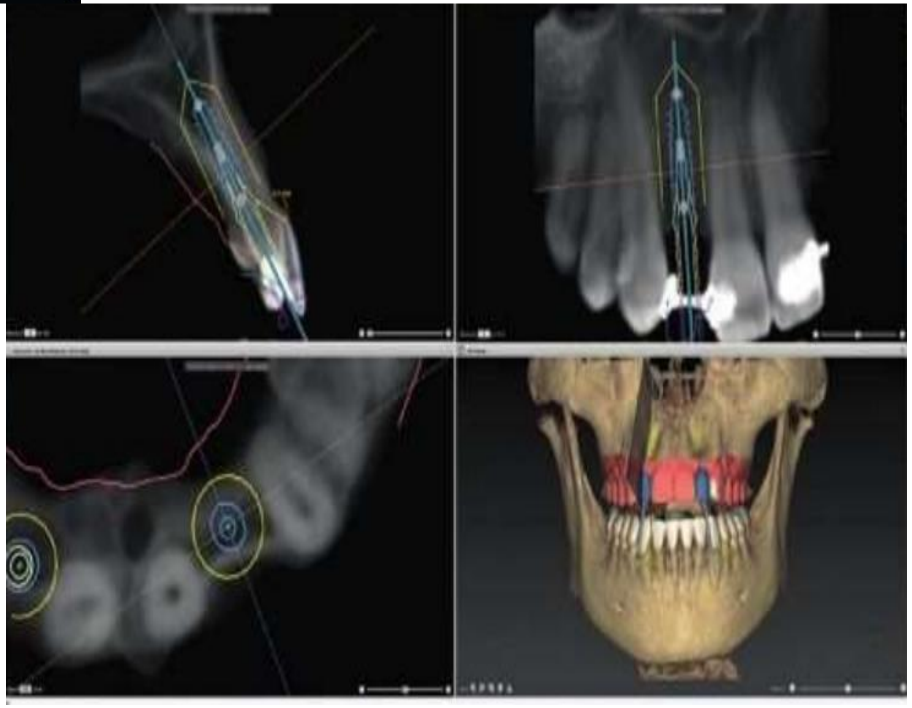
- Implantology and prosthodontics
- Oral and maxillofacial surgery
- Endodontics
- Periodontics
- Orthodontics

Implantology and Prosthodontics



To assess the quantity and • quality of bone in edentulous ridges and implant cases.

- Implant site evaluation, accurate measurements, accurate planning of implant in relation to vital structures, surgical guide,



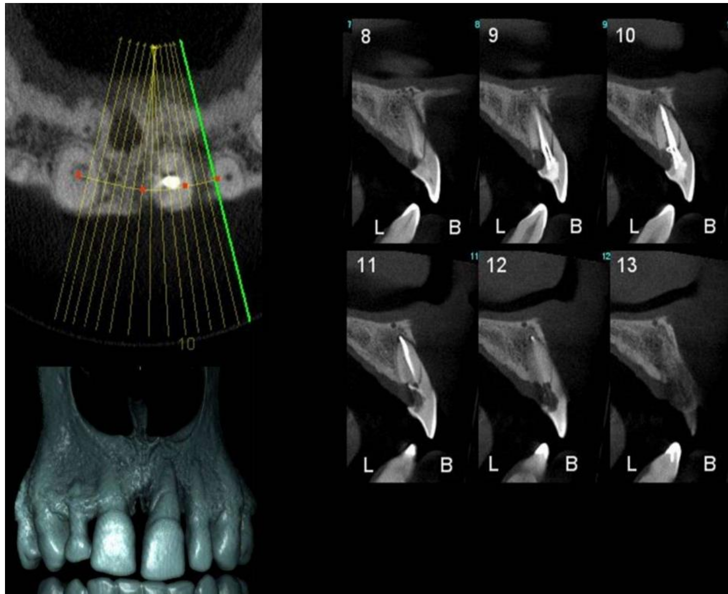
- Computerised ProsthesisEvaluation roots of upper posterior teeth in respect to the maxillary sinus, sinus lift.

Periodontics

- CBCT can be used in assessing a detailed morphologic description of the bone
- Measuring of bony defects, furcation involvement, buccal & lingual defects.

Endodontics

- CBCT is a very useful tool in diagnosing apical lesions
- Crown morphology, pulp chamber, proximal caries
- Root morphology, number of root canals, course and direction of canals, accessory canals, root resorption, root fractures
- Obturation, filling, under and overfilling, sinus problems
- Broken instruments
- Useful in planning periapical endodontic surgery as the anatomical structures such as inferior dental canal, mental foramen, maxillary sinus can be easily differentiated and relation to root can be quantified.

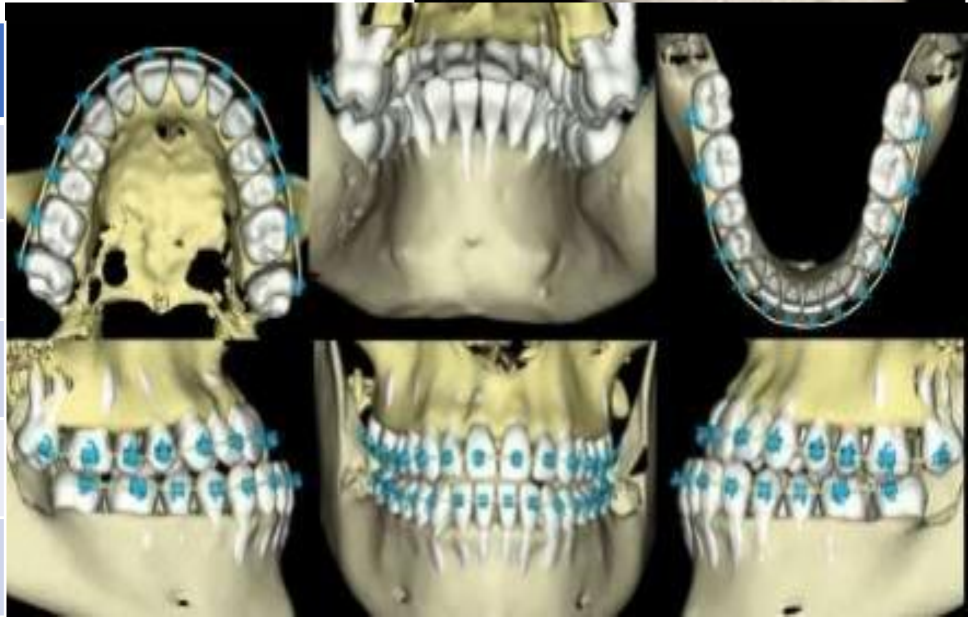


Orthodontics

- Orthodontists can use CBCT images in orthodontic
- Complete hard tissue examination and record, type of dentition present, Arch size, arch shape, symmetry of arches,
- Anteroposterior and transverse maxillo mandibular relationship,
- Number, size of teeth, shape of teeth,

Dosage of intr/extraoral images

Intra-oral ingle	**0.001 mSv up to 0.004 mSv**
Full-mouth set	0.080 mSv
Lateral cephalogram	0.002 mSv
Dental panoramic technique	0.015 mSv
panoramic technique	0.015 mSv
Hospital CT scan (both jaws)	0.6 mSv



Conclusion

- It is vital or any clinician to remain in touch with latest innovations in the field of one's expertise and apply the same fo the benefit of patient care and be ready and willing to accept new trends.
- CBCT is one such recent advancement in the field of Dentistry which one should learn and adapt into clinical practice.

Thank You!