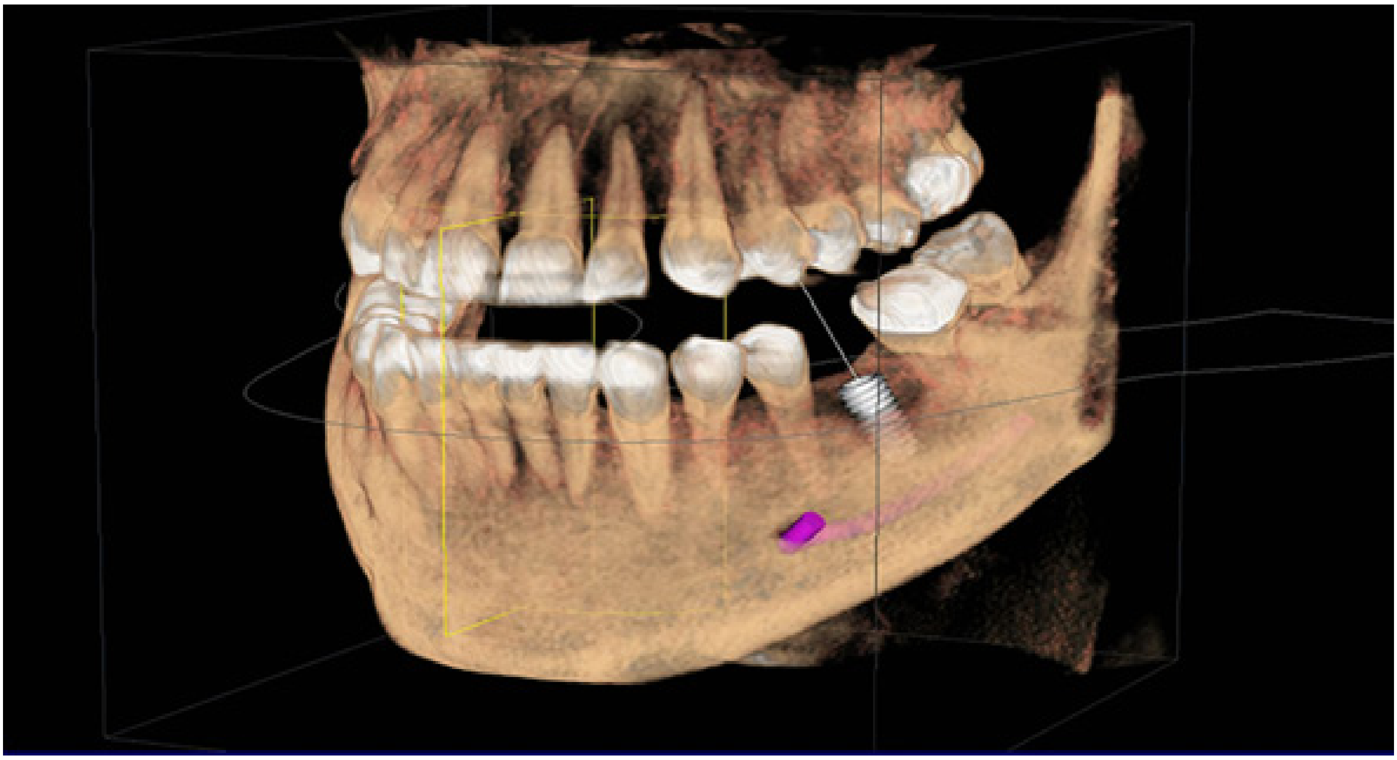
VIEWING THE CONE BEAM COMPUTED TOMOGRAPHY FROM THE WORLD OF DENTISTRY

[1] Madhulika Banerjee, [2] Varsha Rani , [3] Divya
[1]Postgraduate student, Department of Periodontology, Rama Dental College, Hospital & Research Centre, Kanpur, UP.
[2] Postgraduate Student, Department of Periodontology, GDC, Amritsar.
[3] Post graduate student, Department of Conservative Dentistry & Endodontics, Babu Banarsi Das College of Dental Sciences, Lucknow.

Corresponding Author:

Madhulika Banerjee
Postgraduate student, Department of Periodontology, Rama Dental College, Hospital & Research Centre, Kanpur, UP.
Email id: banerjeemadhulika12693@gmail.com Ph. No: 9588074372



Introduction

Dental world is coming up with several new amazing technologies including digital impressions, VELscope, lasers, intraoral cameras, zoom! Whitening, etc. Recently, a new technology has brought a boom! in dentistry and it's "CBCT- Cone Beam Computed Tomography". We all have a very limited knowledge regarding CBCT, but in the field of dentistry it has become an emerging technology. Cone beam computed tomography (CBCT) is an absolutely recent imaging technology used to create 3-dimensional interpretation of subjects. The advantage of this new technique includes the good image quality, volumetric analysis and short scan times. Many fields including orthodontics, oral surgery, implant dentistry, periodontics and endodontics find unique profit of the 3-dimensional reconstructions provided by CBCT. Imaging, especially cone beam computed tomography, has been now approved as one of the most appropriate non-invasive diagnostic procedure. With uses not limited to dental pathologies, radiology has been instrumental in playing a critical role for judging the current treatment plan for overall health of the patient.

Nevertheless, innumerable endeavors have been taken into action to reduce the image distortion and use best interpretation skills to conclude an expedient conclusion. Up to a certain level, cone beam computed tomography has been commendable to reduce such errors but the excessive charges and considerable radiation dose have been responsible to confine its use.[1]

Basic principle of CBCT

CBCT has been the most innovative approach in the sector of imaging with a complete transformation from two dimensional to three-dimensional imaging adding to the image reconstruction as well.[2] The technique has been augmented stupendously due to the availability of CBCT scanners which have been carefully formulated to adequately project the image of Oral and Maxillofacial region.[3] The process of a sole scan involves the revolution of the source of the X-ray tube as well as the sensor surrounding the head and neck region resulting into numerous segmented imaging pictography of the location involved. The pictography done is a part of the raw data collected by the sensor which needs processing. The processing is done in terms of volume elements called Voxels which converts the raw data to the three-dimensional structure by replicating the anatomy of the involved subject. The unit voxels are synchronous to Rubik's cube, as little as 0.1 to 0.4mm for every cube face resulting into a splendid resolution.[4]

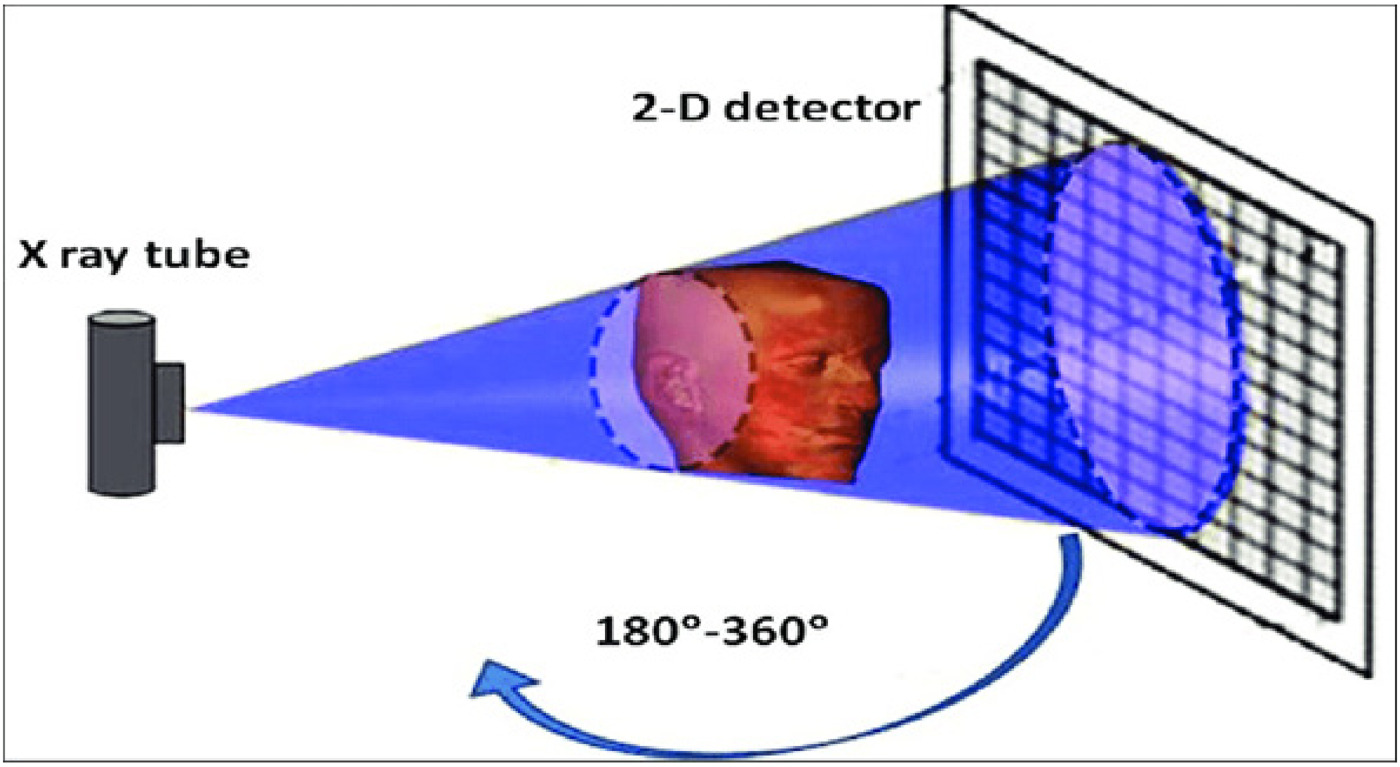


Figure 1: CBCT, Principle of basis image acquisition where in X-ray source and Image receptor reciprocate around patient 180 – 360 degrees to acquire 180 – 1024, 2D cephalometric images.

Application of CBCT in dentistry

Radiographic examination is essential in diagnosis and treatment planning in dentistry. Apart from compressing three-dimensional anatomy of the area being radiographed into a two-dimensional image, 2D imaging possesses unique inherent limitations (including magnification, distortion, and superimposition), together leading to misrepresentation of structures.[5] CBCT produces 3D images useful for many oral & maxillofacial situations (Figure 2) that can guide in diagnosis and assessment of disease severity, planning and delivery of treatment, and follow-up.

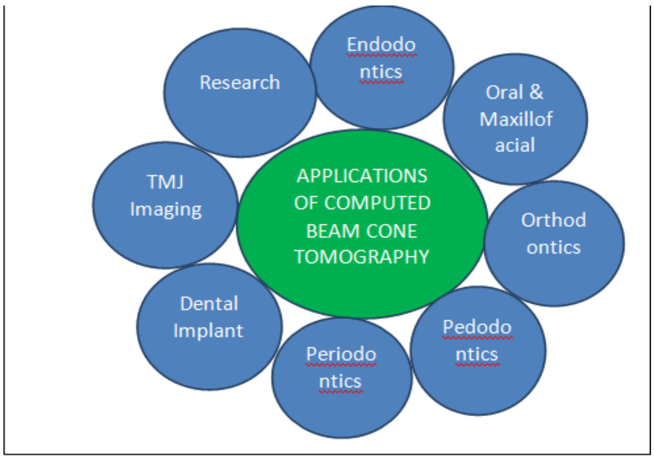


Figure 2: Applications of CBCT in various dental specialties.

Applications in Periodontics

For many decades, 2D imaging was the mainstay in periodontal diagnosis, however, their limitations led to under/over estimation of the bone loss.[6] The literature has confirmed that morphometric analysis of periodontal diseases by CBCT to be as precise as direct measurement using a periodontal probe.[7] In addition, CBCT is far better than 2D radiographs in visualization of buccal and lingual defects due to absence of superimposition of the structures. CBCT offers precise measurement of intrabony defects and lets clinicians to evaluate furcation involvement, dehiscence, fenestration defects, and periodontal cysts and to assess postsurgical consequences of regenerative periodontal treatment.

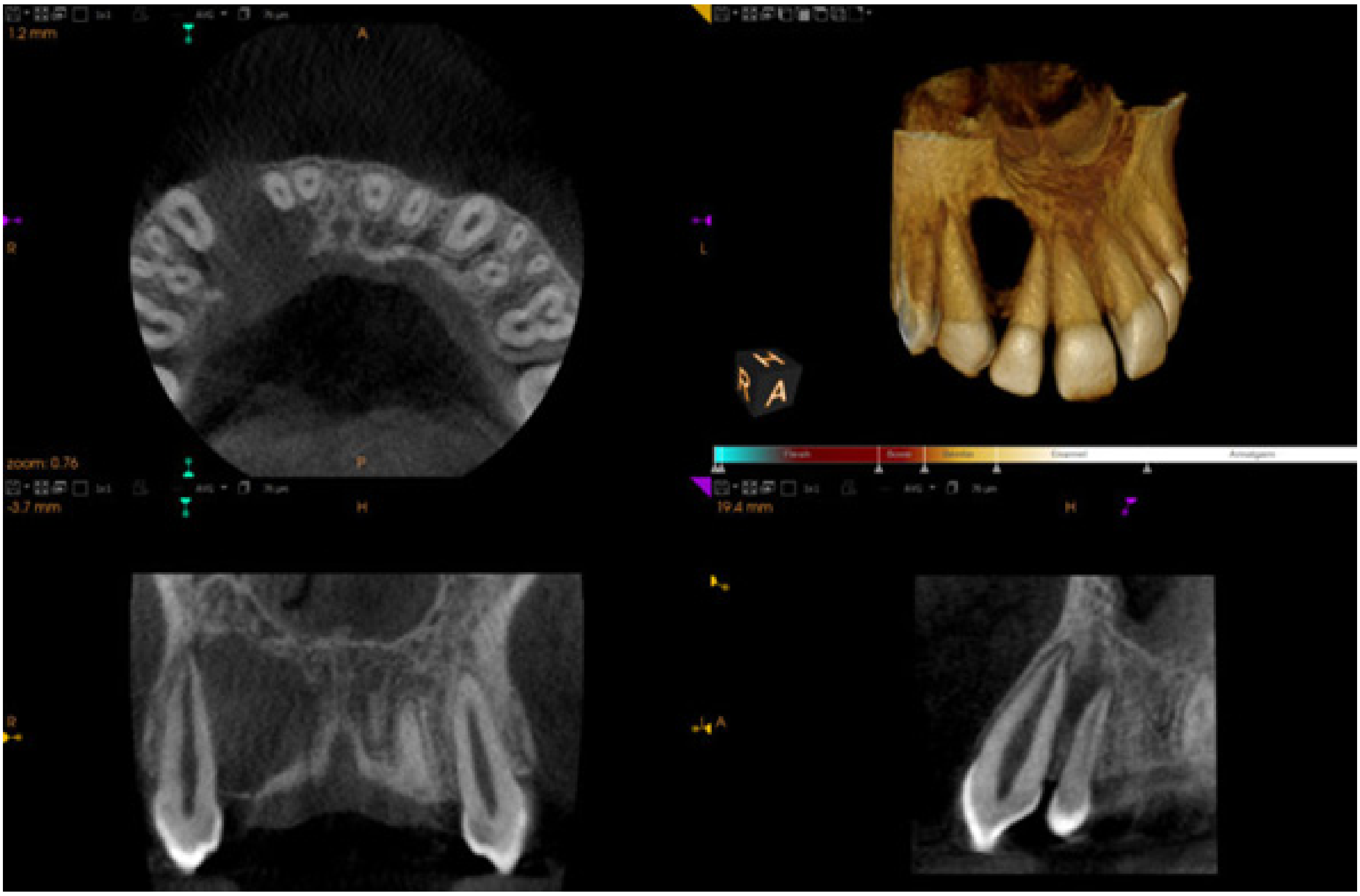


Figure 3: Lateral periodontal cyst, CBCT preoperative scan

Applications in Endodontics:

Intraoral radiography is the preferred imaging method for the evaluation of endodontically treated teeth. Recently, however, CBCT has proven to be a promising diagnostic aid for complex endodontic cases, including the detection and visualization of extra canals, lateral canals, perforations, obturations, canal shape, and vertical root fracture.[8] CBCT has superior diagnostic efficacy in the assessment of complex dental pathologies, malformed teeth, caries extension, differentiation of periapical pathologies, external and internal root resorption, and root fractures.[9] Patel reported a case of dens invaginatus in which a CBCT scan revealed no communication between the invagination and the main root canal, thus preventing unnecessary root canal treatment of the concerned tooth.[10]

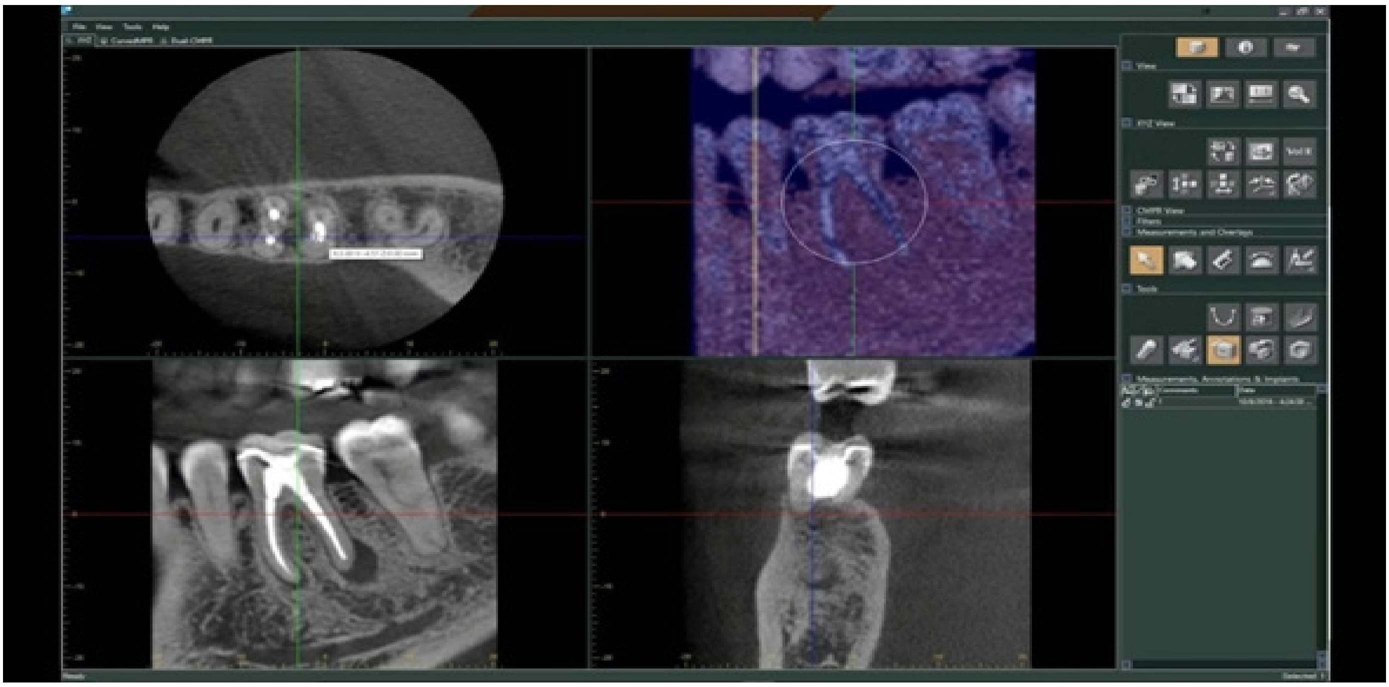


Figure 4: CBCT in endodontics

Applications in Implantology:
CBCT provides cross-sectional images in several planes that help with the accurate assessment of the height, width, and angulation of bone, as well as with visualization of the position of the inferior alveolar canal and mental foramen in the mandible and the sinus in the maxilla. In edentulous patients, CBCT provides better visualization of buccolingual alveolar ridge patterns, such as irregular, narrow crestal, or knife-edge ridge, undulating concavities, and alveolar bone quality and quantity. In many situations, CBCT implantology has minimized or eliminated the need for procedures like bone and tissue grafts, as it enables precise measurement of the distance, area, and volume of the bone in which the implant is to be placed.[11]

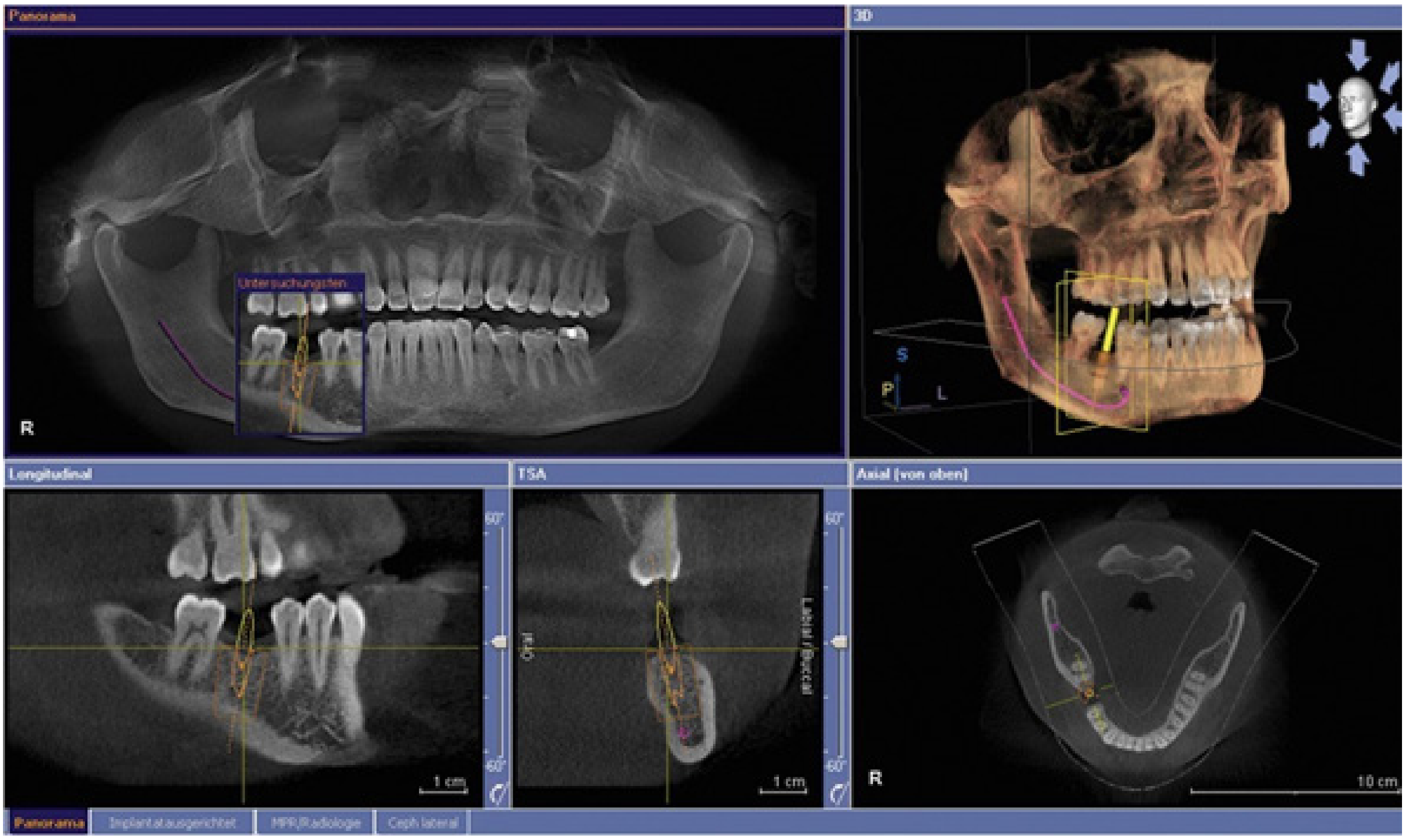


Figure 5: CBCT in dental implant

Applications in Orthodontics:

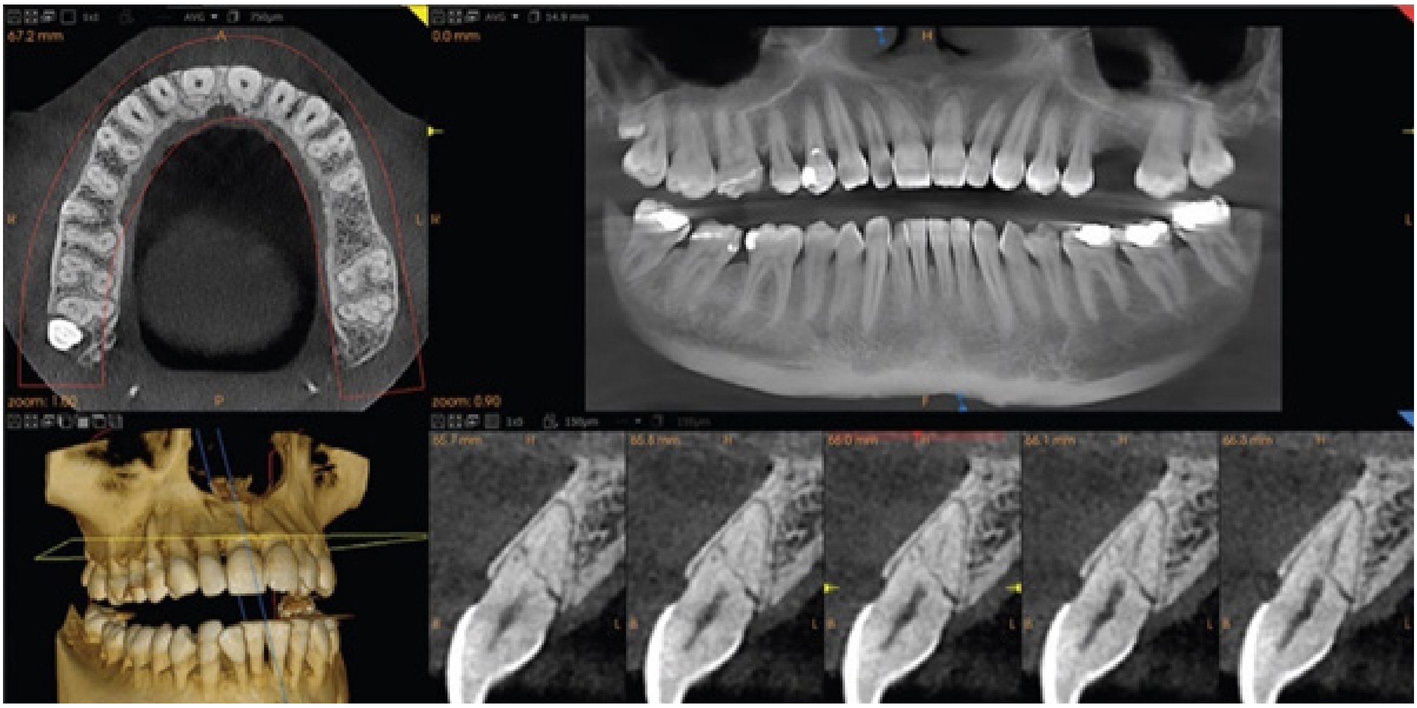


Figure 6: CBCT in orthodontics

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. Some of the orthodontic uses include assessment of palatal bone thickness, skeletal growth patterns, dental age estimation, visualization of impacted teeth 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.[12] The availability of software like Dolphin and In Vivo Dental together with CBCT images for cephalometric analysis has turned out to be the best means for assessing facial growth, age, airway function, and disturbances in tooth eruption. CBCT provides pictorial guides for safe placement of Mini-implants, evading accidental and irreparable injury to the vital structures.[13] The CBCT assessment of airway has become commonplace in many areas of orthodontic research, with anatomical linear and volumetric measurements being used to assess the effect of various orthodontic and surgical treatments. This is despite the fact that a validated and optimized CBCT protocol for airway imaging remains elusive.[14] The upper pharyngeal airway assessment with CBCT demonstrated moderate- to excellent intra- and inter-examiner reliability for volume and minimum cross-sectional area based on the available and sparse evidence. However, due to the fact that CBCT reliability has only been studied in controlled settings, which artificially limits potential sources of variability, caution is advised when interpreting these results.

Applications in Oral & Maxillofacial Surgery:

Considering the limitations of 2D images like structural superimpositions, CBCT permits precise measurement of surface distances. These advantages of CBCT have made it the choice for exploring and handling midfacial and orbital fractures including dentoalveolar fractures, post fracture evaluation, inter operative visualization of the maxillofacial bones, and intra operative navigation throughout procedures.[15] CBCT is used to examine the exact location as well as extension of pathologies like odontogenic and non-odontogenic tumors and cysts of the jaws. Pathologic calcifications (e.g., tonsilloliths, lymph nodes, salivary gland stones) can also be recognized in terms of location and distinguished from possibly noteworthy calcifications, such as those occurring in carotid artery.[16]

Combined with advancements in 3D scanning technologies, such as intraoral and extraoral scanning, cone beam-computed tomography (CBCT), and other CAD/CAM technologies, 3D printing has developed rapidly in the field of maxillofacial surgery.[17] Three-dimensional printing surgery technologies have many unique advantages, particularly in improving the symmetry and functional effects of cranio-maxillofacial plastic surgery techniques.[18] Jacobs and Lin have thoroughly summarized the applications in the cranio-maxillofacial region, including surgical guides, occlusal splints, and implants.[19]

Applications in TMJ Disorders:

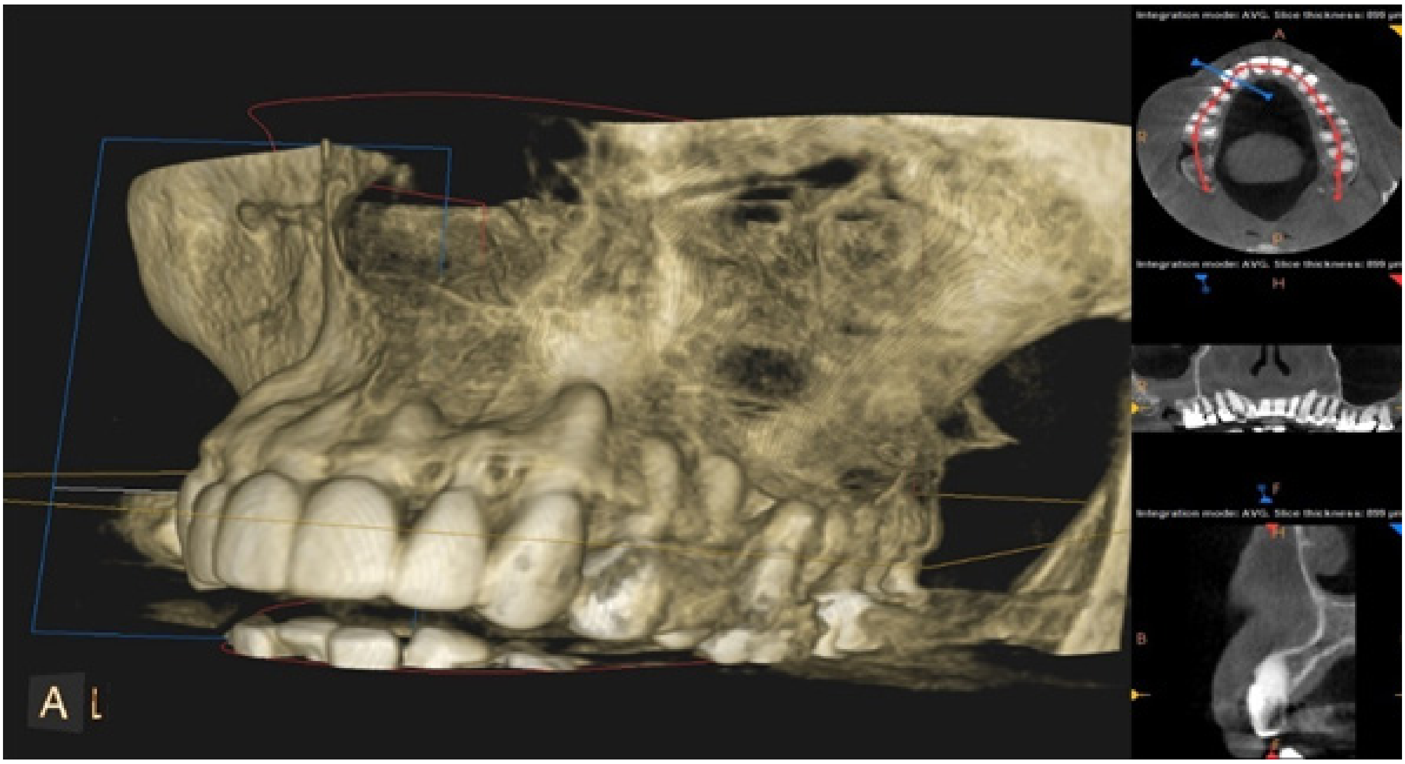


Figure 7: CBCT showing the thin bone biotype in maxilla jaw bone

Temporomandibular joint disorders (TMDs) constitute the most common category of orofacial pain conditions of the temporomandibular joint (TMJ) and its associated musculature. As of now, CBCT has been found to be most useful in the evaluation of bony changes of the TMJ, such as fractures, ankylosis, dislocation, growth abnormalities, and various degenerative joint diseases including osteophytes, erosions, flattening, subchondral sclerosis, and pseudocysts. Analysis of the dynamic relationship of the articular surfaces of the TMJ is necessary to determine the strain undergone by the articular disc while chewing; this strain, if high, may compromise the integrity of the disc. CBCT provides 3D images of the mandibular condyle and surrounding structures to facilitate the analysis and diagnosis of bone morphological features, joint space, and the dynamic function, which serve as the critical keys to treatment outcome in patients with signs and symptoms of TMD.[20,21]

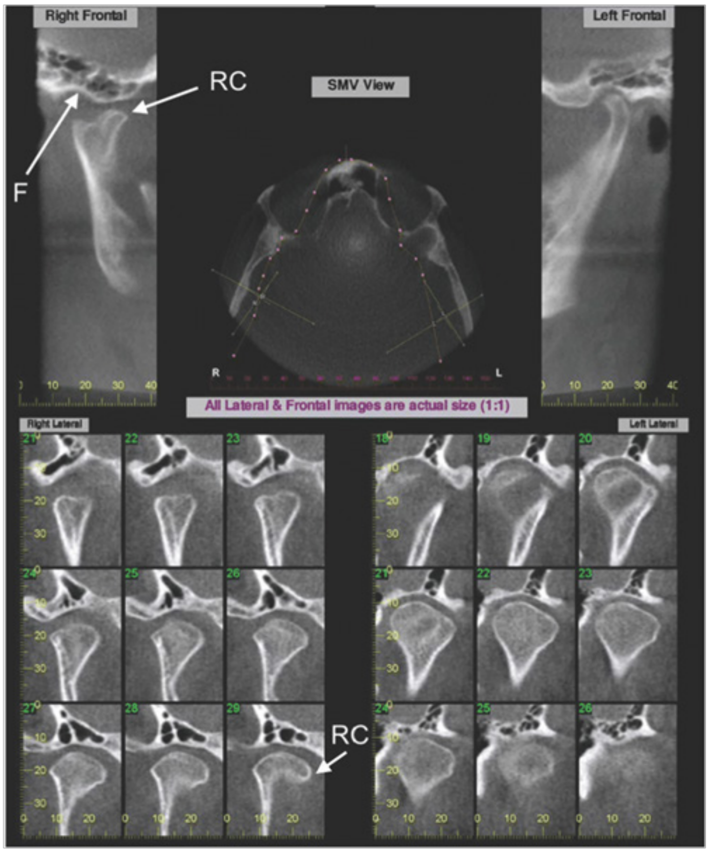


Figure 8: A TMJ series from a CBCT scan showing the regenerated condyle

Future prospective of computed beam cone tomography
Optimization of CBCT images:

Compared with other modalities, CBCT has been documented to have high diagnostic efficacy in the accurate detection of complex oral and maxillofacial pathologies. This efficacy could be increased further by the optimization of CBCT with respect to various parameters, such as reduction in focal spot size, alteration of beam geometry, an increase in detector efficiency, and optimization of exposure and image reconstruction. Moreover, old CBCT scanners mostly have large FOV (Field of Visualization) that results in the production of more scattered radiation, which contributes to an increased radiation dose delivered to the patient. Optimization of old scanners could be achieved by using a small-diameter FOV that covers only the region of interest.[22]

Recently, some machines have utilized the concept of dynamic automatic exposure control, in which exposure is adjusted during acquisition of the image. Image performance could be increased by altering the geometric shape of the beam; this has been achieved by a technique termed off-axis scanning, which utilizes a half cone with a small overlap in the iso-center that increases the FOV to almost twice the diameter as that involved in full-cone scanning. This contributes to a reduction in the dose administered to the patient.

Phase contrast tomography:

The literature includes numerous studies investigating the X-ray absorption of the object under study in phase contrast tomography, but the phase nature of the X-rays still requires further exploration. Recently, researchers have introduced quantitative phase-contrast cone-beam tomography, in which the phase coefficient rather than the attenuation coefficient is used to reconstruct the image. This technique utilizes unfiltered radiation from a small polychromatic source, thus reducing high spatial frequency noise and contributing to high soft tissue contrast.[23]

Conclusion

The basic principle of using CBCT for dental diagnosis and treatment planning is to maximize the clinical benefit to the patient while minimizing the risk of ionizing radiation. Although the CBCT modality offers multiple usefulness, it should be used with caution, with careful consideration of the trade-off between dose and image quality. Despite their diverse uses and technical variability, dentists still need to develop standardized DVT testing protocols. The development of these protocols will help practitioners prescribe this modality for a variety of clinical uses.

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