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CBCT as a Diagnostic Tool in Hard Tissue Imaging in Dentistry: A Review

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Abstract: Cone Beam Computed Tomography (CBCT) has transformed dental and maxillofacial imaging by providing high-resolution, three-dimensional visualization of hard tissues with reduced radiation exposure compared to conventional CT. Its applications span oral medicine & radiology; implantology, oral and maxillofacial surgery, orthodontics, endodontics, periodontics, airway and ENT imaging, craniofacial assessment, and forensic dentistry. CBCT enables precise evaluation of bone morphology, implant site planning, fracture assessment, impacted teeth localization, temporomandibular joint analysis, airway patency, and volumetric measurement of dental and skeletal structures. Integration with computer-aided design, stereolithography, and artificial intelligence further enhances diagnostic accuracy, surgical planning, and treatment outcomes. Limitations include reduced soft tissue contrast, susceptibility to metal artifacts, and the need for specialized operator training. Selective use is recommended when conventional imaging is insufficient, balancing clinical benefit against radiation exposure. Overall, CBCT has become an indispensable tool in modern dentistry and maxillofacial practice, optimizing diagnosis, treatment planning, and patient safety.This article provides an overview of CBCT's role as a diagnostic tool in dental hard tissue imaging.

Keywords: CBCT, Dentistry, Radiology, Oral Medicine, Dental Implantology

I. INTRODUCTION

Cone Beam Computed Tomography (CBCT) has become an indispensable diagnostic tool in dentistry, revolutionizing imaging of the maxillofacial region by offering three-dimensional visualization with high spatial resolution and significantly lower radiation exposure compared to conventional CT.[1] Since the discovery of X-rays in 1895 by Wilhelm Conrad Roentgen and the later introduction of Computed Tomography (CT) by G.N. Hounsfield in 1972, diagnostic imaging has evolved remarkably, moving from conventional two-dimensional (2D) radiography with its inherent limitations of distortion and superimposition to advanced three-dimensional (3D) modalities.[2] Although CT provided superior imaging, its high cost, limited accessibility, and high radiation dose restricted its dental applications. This gap was addressed with the independent introduction of CBCT by Arai in Japan and Mozzo in Italy, which combined cost-effectiveness with high diagnostic quality, leading to its widespread adoption across dentistry.[3] CBCT works by projecting a cone-shaped X-ray beam onto a 2D detector, capturing a series of images in a single rotation that are reconstructed into 3D using cone-beam algorithms, producing isotropic voxels as small as 0.125 mm and high-resolution images of teeth, bone, and adjacent structures.[4] Its advantages include lower effective radiation dose (3–20% of conventional CT), efficient X-ray utilization, reduced energy requirements, and affordability of X-ray tubes compared to medical CT. CBCT has extensive applications across orthodontics, implantology, endodontics, periodontics, and maxillofacial surgery, aiding in the diagnosis of cysts, tumors, infections, developmental anomalies, temporomandibular joint disorders, and traumatic injuries, as well as in precise implant planning and surgical guidance.[5] Depending on the field of view (FOV), CBCT units are classified into large, medium, and limited volume, with smaller FOVs offering higher resolution, lower patient radiation exposure, and targeted imaging of the region of interest through collimation. While early CBCT devices had larger FOVs and higher radiation doses, recent advances such as pulsed radiation, optimized software, and reduced FOVs have further minimized exposure in alignment with the ALARA principle endorsed by the American Dental Association.[6] Importantly, CBCT is not intended to replace conventional radiographs but serves as a complementary tool reserved for specific clinical indications, requiring justification to avoid unnecessary referrals. Emerging innovations, including the integration of artificial intelligence, machine learning, and combined CBCT–optical imaging, hold promise for enhancing diagnostic accuracy and optimizing treatment planning.[7] Thus, CBCT represents a pivotal advancement in dental imaging, balancing diagnostic excellence with radiation safety, and continues to expand its role in both dental and non-dental applications.[8] This article gives an overview about the role of CBCT as a diagnostic tool in hard tissue imaging in dentistry.

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II. PRINCIPLES AND WORKING MECHANISM OF CBCT

Cone Beam Computed Tomography (CBCT) is a specialized imaging technique designed for maxillofacial applications that differs from conventional CT by using a cone-shaped X-ray beam and a flat-panel detector, which rotates once around the patient (180°–360°) to capture the entire region of interest in a single scan, rather than slice-by-slice imaging. This single rotation acquires 180–1024 two-dimensional projections that are reconstructed into volumetric data using the Feldkamp algorithm, thereby reducing radiation exposure by 6–15 times compared to conventional CT.[9] Scanning times typically range from 5 to 40 seconds, with X-ray parameters similar to panoramic radiography (1–15 mA at 90–120 kVp), whereas medical CT requires much higher values (120–150 mA at 220 kVp). The reconstructed images, stored in Digital Imaging and Communications in Medicine (DICOM) format, can be viewed in axial, coronal, and sagittal planes and further manipulated using integrated or third-party software for diagnosis, treatment planning, surgical guide fabrication, and virtual modeling. CBCT also allows the creation of panoramic-like views, cephalometric reconstructions, and multiplanar reformations such as oblique slicing for evaluating impacted teeth or Temporomandibular joints, curved slicing to trace jaw arches, and cross-sectional views to assess alveolar bone morphology for implants or third molar relations.[10] Additional display modes include ray-sum imaging for virtual panoramic or cephalometric projections, and volume rendering (direct methods such as maximum intensity projection for detecting calcifications, fractures, or TMJ changes, and indirect methods for 3D volumetric reconstructions with surface or transparent views).[11] The choice of field of view (FOV)small, medium, or largedepends on clinical requirements, with smaller FOVs offering higher resolution, reduced scatter, and lower radiation, making them ideal for endodontics and localized implant planning, while medium and large FOVs are preferred in orthodontics, pathology assessment, and craniofacial surgical planning. Compared to conventional CT, CBCT offers compact size, lower cost, shorter scan times, and substantially reduced radiation exposure, although it has limitations such as lower soft tissue contrast and higher dose relative to traditional 2D radiography.[12]

III. PROCEDURE

Key components include the Gantry Arm and Patient Support Columns, which form the main frame and hold the patient. Mounted on the rotating part of the gantry are the X-Ray Source and the Flat Panel Console/Detector, which are positioned opposite each other. The patient is seated in the Patient Source (likely intended to be Patient Seat or Support), which includes a head-stabilization piece (the small white tube near the patient's face is a positioning aid, and the vest is a protective lead apron). During a scan, the patient is instructed to remain completely still while the Gantry Arm slowly rotates a full or partial circle (typically 180◦ to 360◦) around the patient's head[10](figure 2).This movement causes the X-Ray Source to emit a cone-shaped beam of radiation, which passes through the patient's head and is captured by the Flat Panel Detector, acquiring hundreds of planar images that are then digitally reconstructed to form the final 3D volume. The patient is positioned, typically with the aid of a chin rest, bite fork, or other head-restraint mechanism, and is instructed to remain completely still. The patient's body remains stationary, and the only movement during the procedure is the rotation of the gantry. The Gantry rotates in a single, continuous arc—usually a full 360◦ rotation or a partial arc (e.g., 180◦ to 200◦)—around a fixed point (the region of interest) within the patient's head(figure 1).During this single rotation, the X-ray Source emits a cone-shaped beam, and the detector captures hundreds of planar projection images from different angles. These 2D images are then processed by a computer to reconstruct the final 3D volume. Patient movement during this rotation, such as nodding, lateral rotation, or even swallowing, is a major concern as it can cause artifacts (e.g., blurring or double contours) and degrade the image quality.[11]

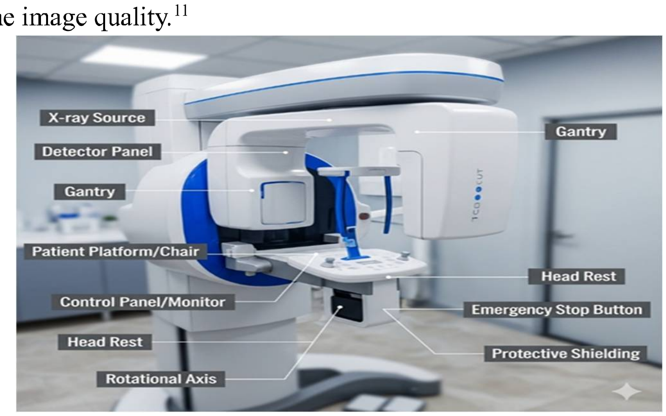

Figure 1: CBCT machine and its parts.

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Figure 2: Patient Positioning

IV. APPLICATIONS OF CBCT IN DENTISTRY

A. Applications of CBCT in the Diagnosis of Oral Medicine and Radiology

Cone Beam Computed Tomography (CBCT) plays a crucial role in oral medicine by enabling accurate diagnosis and assessment of a wide range of oral lesions through detailed three-dimensional visualization of the maxillofacial region. It is particularly valuable in detecting and characterizing cysts, benign and malignant tumors, fibro-osseous lesions, and other intraosseous pathologies, offering superior localization, size estimation, and evaluation of lesion margins compared to conventional radiographs.[12] CBCT allows clinicians to assess cortical plate expansion, thinning, or perforation, involvement of adjacent anatomical structures, and displacement or resorption of teeth, which are key indicators in differentiating lesion types and planning management. In cases of odontogenic infections or inflammatory conditions such as osteomyelitis, CBCT reveals sequestra, periosteal reactions, and extent of bone involvement with high precision. Similarly, it aids in the diagnosis of mucormycosis and sinus-related pathologies by evaluating bone destruction and calcifications. For potentially malignant and malignant oral lesions, CBCT provides valuable information on bone invasion and tumor spread, guiding surgical planning and prognosis assessment. Its ability to produce multiplanar and volumetric reconstructions enhances diagnostic accuracy, minimizes reliance on exploratory surgery, and supports longitudinal monitoring of lesion progression or treatment response, thereby making CBCT an indispensable adjunct in the diagnostic armamentarium of oral medicine.[13]

B. Applications of CBCT in Dental Implantology

Cone Beam Computed Tomography (CBCT) has become the imaging modality of choice in implantology, revolutionizing the way missing teeth are replaced with dental implants by providing accurate, three-dimensional assessment of implant sites while minimizing radiation exposure compared to conventional CT.[13] Traditional two-dimensional radiographs often suffered from magnification errors, distortion, and superimposition of structures, limiting their accuracy, while CT, though more precise, posed challenges of high cost and radiation dose. CBCT overcomes these limitations by offering detailed cross-sectional and volumetric images that allow clinicians to evaluate bone height, width, angulation, and the relationship of proposed implant sites to vital anatomical structures such as the inferior alveolar canal, mental foramen, and maxillary sinus.[14]

This precise visualization reduces implant failures and surgical complications, and facilitates preoperative and postoperative assessments of grafts, alveolar bone quality, and implant positioning. Although CBCT cannot provide true Hounsfield unit values like conventional CT, it offers reliable subjective assessment of bone quality, which is critical for predicting implant success since poor bone density, especially type IV bone in the posterior maxilla, is associated with higher failure rates.[15] Furthermore, CBCT data, integrated with computer-aided design and manufacturing technology, enables the fabrication of computer-generated surgical guideswhether tooth-supported, mucosa-supported, or bone-supportedthat enhance the precision of guided implant placement and support minimally invasive, flapless surgeries, thereby reducing operative time, postoperative pain, and recovery duration. With stereolithographic models and digital planning, restorations such as immediate prosthesis placement (e.g., "Teeth-in-an-Hour™") have become possible, improving patient outcomes and satisfaction.[16] CBCT also aids in identifying vascular canals in the maxillary sinus to prevent intraoperative bleeding, assessing palatal thickness for miniscrew placement, and evaluating edentulous ridge morphology.[17]

C. Applications of CBCT in Oral and Maxillofacial Surgery

Cone beam computed tomography (CBCT) has become an invaluable imaging modality in oral and maxillofacial surgery, owing to its ability to overcome the limitations of 2D radiography such as magnification errors, distortion, and superimpositions. With its 3D imaging capability, CBCT allows precise assessment of midfacial, orbital, mandibular, and dentoalveolar fractures, making it the preferred choice over conventional radiographs in complex trauma cases, including non-displaced condylar fractures and comminuted facial fractures.[18] It facilitates preoperative, intraoperative, and postoperative evaluation by providing accurate visualization of fracture lines, bone displacement, and spatial relationships of vital structures, with reduced artifacts compared to CT in cases involving metal objects. CBCT also aids in diagnosing odontogenic and non-odontogenic cysts and tumors, osteomyelitis, osteonecrosis, and sinus pathologies, while enabling surgical planning for impacted teeth, orthognathic procedures, sinus floor augmentations, bone graft assessments, and implant surgeries. Its application extends to evaluating impacted or supernumerary teeth, detecting pathological calcifications, and assessing temporomandibular joint morphology, glenoid fossa thickness, and condylar position.[19] Furthermore, CBCT provides a dose- and cost-effective alternative to CT in imaging osseous structures, while MRI remains superior for soft tissue assessment. In dentoalveolar trauma, CBCT demonstrates higher diagnostic accuracy than periapical or panoramic radiographs in detecting root and alveolar fractures, with voxel size optimization enhancing sensitivity and specificity, though metal artifacts may reduce diagnostic precision. Intraoperative CBCT has gained traction for guiding fracture reduction, implant placement, and orbital reconstructions, reducing revision rates and improving surgical outcomes, particularly in complex anatomical regions such as the zygomaticomaxillary complex, orbit, and condylar head.[20]

D. CBCT in Temporomandibular Joint and Craniofacial Surgical Applications

Cone Beam Computed Tomography (CBCT) has emerged as a highly effective imaging modality for evaluating the temporomandibular joint (TMJ), providing multiplanar and three-dimensional visualization of the condyle and surrounding structures. It enables assessment of joint space, condylar position within the fossa, and detection of conditions such as dislocation, ankylosis, cortical erosion, rheumatoid arthritis, and cysts. CBCT also proves valuable in quantifying the glenoid fossa roof and identifying adjacent soft tissue structures, thereby reducing reliance on MRI, which remains superior for disc displacement evaluation but limited in diagnosing osseous changes.[21] Beyond TMJ evaluation, CBCT plays a pivotal role in craniofacial and orthognathic surgery. In cleft lip and palate cases, it offers precise volumetric assessment of alveolar and palatal bone defects while minimizing radiation compared to conventional CT, aiding in treatment planning, arch alignment, and palatal expansion. For orthognathic surgery, CBCT overcomes limitations of lateral cephalography by enabling accurate 3D modeling, virtual surgical planning, and geometric precision in complex cases such as hemifacial microsomia.[22] Advanced systems, like GALILEOS with FaceScanner integration, further enhance clinical applications by superimposing 3D facial scans with CBCT images, thus improving diagnostic accuracy, surgical prediction, and patient education.

E. Cone Beam Computed Tomography (CBCT) in Orthodontics

CBCT offers superimposition-free images that are self-corrected for magnification, with a practical 1:1 measuring ratio, enabling accurate morphometric analysis of structures and anatomic relationships critical for orthodontic treatment. Its applications include assessment of palatal bone thickness, skeletal growth patterns, dental age estimation, impacted teeth localization, root angulation, tooth inclination and torque, available alveolar bone width for buccolingual movement, upper airway evaluation, and planning of orthognathic and facial orthomorphic surgeries.[23]

CBCT also facilitates cephalometric analysis with advanced software such as Dolphin and InVivo Dental, enhancing the assessment of facial growth, age, airway function, and disturbances in tooth eruption. Small FOV CBCT is indicated for specific orthodontic cases where conventional radiographs are insufficient, such as unerupted maxillary canines, dilacerated or supernumerary teeth near the inferior alveolar canal, and clefts requiring grafting, whereas large FOV CBCT is useful in orthognathic surgery planning where 3D data are essential.[24] has proven valuable for evaluating complex dentoskeletal relationships, impacted or transposed teeth, cleft lip and palate defects, root resorption, cervical vertebral maturation, sites for auto-transplantation, and surgical planning for exposure or forced eruption of impacted canines. For maxillary impacted canines, CBCT enhances visualization of tooth position, dilaceration, proximity to roots, alveolar boundary conditions, and surgical access planning, thereby increasing clinician confidence.[25] In cleft lip and palate cases, it enables visualization of 3D bone morphology, selection of graft donor sites, and evaluation of alveolar bone graft outcomes. CBCT also aids in transverse dimension analysis for maxillary expansion, integration with surface imaging, 3D cephalometry, and research into orthodontic-related paraesthesia. Its utility extends to safe placement of mini-implants by guiding insertion and avoiding vital structures, assessment of bone density changes during treatment, and detection of neighboring root resorption due to ectopic teeth.[32] Studies have validated CBCT's superior accuracy in cephalometric landmark identification and linear measurements compared to traditional cephalograms, confirming its reliability as a diagnostic and treatment planning tool. With the advent of AI-based software for virtual tooth movement and enhanced analysis, CBCT continues to revolutionize orthodontics by offering precise, comprehensive, and clinically relevant 3D imaging that optimizes diagnosis, treatment outcomes, and patient safety.[26]

F. Applications of Cone Beam Computed Tomography (CBCT) in Endodontics

Cone Beam Computed Tomography (CBCT) has emerged as a powerful diagnostic and treatment-planning tool in endodontics, particularly when conventional radiographs are inconclusive. A small field of view (FOV) CBCT is recommended in cases where lower-dose 2D imaging does not provide sufficient information, and its use is likely to alter the diagnosis and treatment plan.[25] The European Society of Endodontology advocates its selective use for evaluation of dentoalveolar trauma, complex root canal anatomy, endodontic complications such as post perforations, root resorption, obliterated canals, detection of periradicular bone changes, and pre-surgical assessment prior to endodontic surgery.[26] Literature demonstrates CBCT's superiority over 2D imaging in characterizing periapical lesions, their relation to critical structures such as the maxillary sinus and mandibular canal, and in differentiating endodontic from non-endodontic pathoses. It enables detailed assessment of root morphology, working length determination, root angulation, obturation quality, and classification of lesions, while providing enhanced detection of vertical and horizontal root fractures due to the absence of superimposition.[27] CBCT also facilitates early diagnosis of internal and external resorption, localization of fractured instruments, assessment of pulpal extensions in developmental anomalies like talon cusps, and evaluation of biomechanical preparation efficacy.Its utility extends to differentiating granulomas from cysts through density measurements, planning endodontic surgeries, identifying additional or accessory canals such as MB2 in maxillary molars, and managing complex cases like dens invaginatus.[28] Limited-volume CBCT is generally preferred over large-volume scans in endodontics due to higher spatial resolution and reduced radiation exposure, making it optimal for tasks like detecting calcifications, accessory canals, apical deltas, and subtle fractures. Additionally, CBCT enhances caries detection, particularly in unrestored teeth, by improving sensitivity while maintaining specificity, although metallic restorations may cause artifacts that reduce diagnostic accuracy. By providing precise visualization of root canal systems, pathoses, and their anatomical relationships, CBCT significantly contributes to accurate diagnosis, treatment planning, and successful endodontic outcomes.[29]

G. Applications of Cone Beam Computed Tomography (CBCT) in Periodontics

For decades, two-dimensional imaging has been the primary method for periodontal diagnosis, yet its limitations often led to underestimation or overestimation of bone loss. CBCT has emerged as a valuable adjunct, offering morphometric analysis of periodontal structures with precision comparable to direct periodontal probing. Unlike conventional radiographs, CBCT allows three-dimensional visualization of buccal and lingual defects without superimposition, enabling accurate assessment of intrabony defects, furcation involvement, dehiscence, fenestration, and periodontal cysts, as well as evaluation of postsurgical outcomes following regenerative therapy. Although bitewing radiographs remain the standard for detecting dental caries, CBCT can incidentally identify carious lesions when scans are obtained for other purposes, though its lower resolution and susceptibility to metallic artifacts may limit caries detection.[30] CBCT provides detailed morphologic information about alveolar bone quantity and architecture, and its volumetric rendering facilitates preoperative planning for implant placement, evaluation of periodontal ligament space, and determination of alveolar bone volume.

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It is particularly valuable in assessing the position of the inferior alveolar canal relative to mandibular third molars, reducing the risk of nerve injury.[31] Studies consistently demonstrate that CBCT outperforms conventional intraoral radiographs in detecting intrabony defects, furcation involvement, and periodontal abnormalities, offering higher inter-examiner agreement, improved diagnostic accuracy, and more precise treatment planning. Furthermore, CBCT can characterize root concavities and associated bone loss patterns, measure hard and soft tissue thickness, evaluate fenestrations, and support assessment of periodontal biotype.[32] While CBCT is not recommended for routine periodontal assessment, it is especially useful in complex cases, post-regenerative treatment evaluation, and surgical planning, providing accurate, reproducible measurements that enhance prognostic evaluation and clinical decision-making. The American Academy of Periodontology supports the use of CBCT for detailed assessment and post-surgical evaluation of furcation involvement and regenerative outcomes, reinforcing its role as a valuable complement to conventional clinical and radiographic methods in periodontic therapy.[33]

H. Applications of CBCT in Forensic Dentistry and Skeletal Assessment

Cone-beam computed tomography (CBCT) has emerged as a valuable non-invasive tool in forensic dentistry and skeletal age assessment, offering accurate three-dimensional visualization of dental and craniofacial structures. In age estimation, CBCT enables detailed evaluation of the pulpo-dentinal complex, which undergoes physiologic and pathological changes with advancing age, without the need for tooth extraction or sectioning. CBCT provides precise measurements of pulp chamber size, tooth volume, and secondary dentin deposition, allowing reliable dental age estimation through techniques such as voxel-counting software to calculate pulp-to-tooth volume ratios.[34] Beyond dental age, CBCT facilitates facial reconstruction by accurately measuring soft tissue thickness at specific craniofacial landmarks, improving identification of skeletal remains across populations. In forensic investigations, CBCT is used for postmortem imaging, localization of high-density metal projectiles in gunshot injuries, and assessment of structural hard-tissue damage with superior resolution compared to multidetector CT. Additionally, CBCT has shown high sensitivity and specificity in diagnosing salivary gland pathologies, including sialoliths, ductal strictures, and stenoses, through CBCT sialography, particularly in complex cases where conventional 2D radiography or ultrasonography may be insufficient. The modality also extends to skeletal age assessment via volumetric imaging of the cervical vertebrae, allowing segmentation of individual vertebrae and providing a three-dimensional approach to biological aging and disease evaluation, such as fractures related to osteoporosis.[35]

I. Advanced Applications and Future Perspectives of CBCT in Dentistry and Beyond

Cone-beam computed tomography (CBCT) has evolved into a multifaceted imaging modality with applications extending far beyond traditional dentomaxillofacial diagnostics. One of its key utilities lies in virtual treatment planning and simulation, particularly in implantology, where CBCT data can be integrated with primary or third-party software to create surgical guides, either via image-guided navigation or rapid prototyping using additive manufacturing technologies.[36] These precise models allow for mock surgeries in complex cases such as trauma, tumor resection, distraction osteogenesis, and implant placement, enhancing clinician confidence while reducing surgical and anesthetic time. CBCT can also be fused with stereophotography or intraoral optical scans to produce comprehensive 3D visualizations of craniofacial structures, enabling evaluation of hard and soft tissue interactions, longitudinal monitoring, and orthognathic surgery planning. Future perspectives involve optimization of CBCT imaging through improvements in focal spot size, beam geometry, detector efficiency, exposure control, pulsed X-ray systems, and advanced image reconstruction techniques such as the algebraic reconstruction method combined with metal artifact reduction. Innovations like real-time dual-energy imaging and integration with artificial intelligence and deep learning aim to improve diagnostic accuracy for periodontal disease, peri-implantitis, and early detection of oral pathologies, while GPU-accelerated reconstruction significantly reduces computation times.[37] Optical scanning in combination with CBCT facilitates high-resolution surface and occlusal mapping, enhancing minimally invasive surgical planning and enabling evaluation of orthodontic or orthognathic treatment effects on facial structures. Beyond dental applications, CBCT has proven valuable in visualizing non-odontogenic pathologies including sinus diseases, mucosal abnormalities, and calcifications, offering superior spatial resolution compared to multidetector CT, while MRI remains preferable for soft tissue and skull base tumors. CBCT is also increasingly used in airway analysis for cleft lip/palate and obstructive sleep apnea, swallowing function assessment, and low-dose musculoskeletal imaging, including interventional procedures such as vertebroplasty, nucleoplasty, and bone biopsies, often combined with fluoroscopy or MRI fusion for precise lesion targeting. Advanced phase-contrast CBCT is being explored for enhanced soft tissue contrast, and C-arm flat-panel units facilitate guidance in interventional radiation therapy with reduced radiation exposure for patients and staff. [38]

J. Advantages of Cone Beam Computed Tomography (CBCT)

Cone Beam Computed Tomography (CBCT) offers multiple advantages that have greatly enhanced diagnostic accuracy, treatment planning, and patient safety in oral medicine. By providing high-resolution three-dimensional images of teeth, jaws, and surrounding craniofacial structures, CBCT enables clinicians to assess complex anatomical relationships that are often difficult to interpret on conventional two-dimensional radiographs. Its precise imaging supports accurate treatment planning in implantology, orthodontics, and oral surgery, allowing detailed evaluation of bone volume, tooth position, and pathology. Compared to conventional CT, CBCT delivers significantly lower radiation doses due to its cone-shaped beam and single-rotation scanning, making it safer for repeated and pediatric applications. Additionally, CBCT units are compact, cost-effective, and suitable for in-office imaging, eliminating the need for hospital referrals. Beyond this, CBCT provides valuable insights into temporomandibular joint morphology, airway evaluation, root canal anatomy, impacted teeth, and bone defects, thereby improving diagnostic confidence. Furthermore, interactive 3D visualization enhances patient education and communication, fostering better understanding and informed consent.[2,18,21]

K. Diagnostic Accuracyand Limitations of CBCT

Cone-beam computed tomography (CBCT) offers high-resolution, three-dimensional imaging that is particularly well-suited for evaluating hard tissues such as bone microarchitecture, providing superior spatial resolution compared to conventional CT, though traditional CT retains an advantage in soft tissue contrast. CBCT delivers lower radiation doses than multidetector CT (MDCT), making it preferable for repeated dental imaging, while digital radiographs and faster film speeds further reduce radiation exposure. Despite its advantages, CBCT has limitations, including reduced soft tissue differentiation, susceptibility to artifacts from metallic restorations, distortion of Hounsfield units that precludes accurate bone density assessment, and the need for patient immobility during relatively long scan times. Scatter radiation can reduce image contrast, reinforcing its primary indication for hard tissue evaluation rather than soft tissue imaging.[39] The American Academy of Oral and Maxillofacial Radiology (AAOMR) recommends CBCT judiciously in implantology and surgical planning, advising panoramic and periapical radiographs for initial assessments, while reserving CBCT for preoperative cross-sectional imaging, complex site development, sinus or bone grafting, impacted teeth evaluation, and postoperative assessment in symptomatic cases or anticipated implant retrieval. Advantages of CBCT include reduced radiation exposure, high diagnostic accuracy for fractures, defects, and implant planning, smaller equipment footprint, and streamlined workflow, while limitations involve metal artifacts, limited soft tissue visualization, and the need for specialized training. Emerging integrations with artificial intelligence and machine learning enhance diagnostic capability and treatment planning, offering potential for automated detection of pathologies, improved implant and periodontal planning, and early intervention in oral diseases, making CBCT a powerful, though carefully applied, tool in modern dentistry.[40]

V. COMPARISON BETWEEN CBCT, CT &OPG[41]

Parameter	OPG (Orthopantomogram)	CT (Conventional Medical CT)	CBCT (Cone Beam CT)
Imaging type	2D panoramic radiograph	3D cross-sectional imaging with fan-shaped X-ray beam	3D volumetric imaging with cone-shaped X-ray beam
Resolution	Low–moderate (limited details, superimpositions common)	High resolution, excellent soft tissue contrast, good bone detail	High spatial resolution for hard tissues, less effective for soft tissues
Radiation dose	Low	High	Moderate (lower than CT, higher than OPG)
Cost & availability	Low cost, widely available in dental practice	High cost, limited to hospitals or major centers	Moderate cost, increasingly available in dental and ENT practices
Field of View (FOV)	Full dental arches in one image	Large (craniofacial, head, neck, whole body)	Adjustable (small, medium, large FOV) depending on clinical need
Soft tissue imaging	Poor	Excellent	Limited (mainly hard tissue evaluation)
Applications	Screening, impacted teeth, trauma overview, general dental	Oncology, trauma, head & neck pathology, soft tissue tumors,	Implant planning, orthodontics, TMJ evaluation, oral lesions, fractures,

Parameter	OPG (Orthopantomogram)	CT (Conventional Medical CT)	CBCT (Cone Beam CT)
	assessment	complex craniofacial conditions	airway analysis, pathology
Advantages	- Quick and inexpensive - Widely available - Low radiation exposure	- Excellent for soft tissues - Wide field of view - Gold standard for complex pathologies and oncology	- High accuracy for bone and dental structures - Lower radiation than CT - Compact and office-based - Precise 3D planning
Disadvantages	- 2D only (distortion, magnification errors, superimposition) - Limited diagnostic detail	- Very high radiation - Expensive - Not typically available in dental clinics - Requires hospital setup	- Susceptible to metal artifacts - Limited soft tissue visualization - Higher dose than OPG - Requires training for interpretation

VI. CONCLUSION

CBCT has transformed dental diagnostics by providing highly accurate, three-dimensional imaging of hard tissues, enhancing clinical decision-making and improving patient outcomes when used appropriately. While exceptionally effective for visualizing bone and dental structures, CBCT is less ideal for soft tissue assessment, where fan-beam CT offers superior resolution and clarity for overlapping anatomical features. Optimal use of CBCT necessitates a solid understanding of dental anatomy and pathology, along with proficiency in image acquisition and reconstruction software.CBCT is a powerful tool for hard tissue evaluation in dentistry, offering enhanced diagnostic precision and treatment planning capabilities, but its application should be guided by clinical indications and operator expertise, with alternative imaging modalities considered for soft tissue assessment.

VII. ABBREVIATIONS

- CBCT: Cone Beam Computed Tomography
- CT: Computed Tomography
- ENT: Ear, Nose, and Throat
- DICOM: Digital Imaging and Communications in Medicine
- FOV: Field of View
- ALARA: As Low As Reasonably Achievable
- TMJ: Temporomandibular Joint
- MRI: Magnetic Resonance Imaging
- MDCT: Multidetector Computed Tomography
- AAOMR: American Academy of Oral and Maxillofacial Radiology
- GPU: Graphics Processing Unit
- OPG: Orthopantomogram
- 2D: Two-dimensional
- 3D: Three-dimensional

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