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CBCT in Dentistry: A Revolution

Ashish Ranjan, Ashish Kumar, Azhar Akhtar, Raghib Hussain, Neeraj Kumar, Firdaus Malka, Dipika Suman*

Sarjug Dental College and Hospital, Darbhanga, Bihar, India

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***Corresponding author:** Dipika Suman, Sarjug Dental College and Hospital, Darbhanga, Bihar, India

ABSTRACT

X-ray images are Usually needed in order to diagnose the problems of our patients who approaches to dentistry clinics with their problems. In cases where the diagnosis cannot be made with conventional x-ray techniques, it may be necessary to resort to advanced imaging techniques such as cone beam computed tomography (CBCT).Cone Beam Computed Tomography (CBCT) introduces a more complex and accurate imaging with 3-D visualization as compared to usual analog and digital radiographs.It is a precise technology for numerous clinical oral-maxillofacial indications, with the added advantage of lower radiation doses than Compuerized Tomography.Alike medical CT, 3 dimensional evaluation of the maxillofacial region with minimal distortion is offered by the CBCT. This article gives an overview of basics of CBCT technology and reviews the specific application of CBCT technology to oral and maxillofacial region with few illustrations.

Keywords: CBCT, Dentistry

INTRODUCTION

A new development in medical history occurred with Sir Wilhelm Conrad Roentgen's discovery of X-rays in 1895. Due to the incorporation of varied imaging technology with complex physical principles over the past few decades, diagnostic imaging has become much more polished. Three-dimensional imaging (3D) developed to satisfy the requirements of cutting-edge technologies in treatment delivery and was also helpful in the implementation of novel treatment modalities. There is scepticism that two-dimensional (2D) radiography, which was the foundation of diagnostic imaging for many years, will continue to contribute given its limitations (superimpositions, distortions, etc.). Computerized transverse axial scanning was first introduced by G.N. Hounsfield in 1972, and this eventually led to the development of computed tomography (CT).[1,2]

The main reasons for CT's underuse in dentistry, however, were its high price, narrow access, and significant radiation exposure. Cone Beam Computed Tomography (CBCT) was developed independently by Arai et al. in Japan and Mozzo et al. in Italy for use in oral and maxillofacial applications. Like CT, CBCT enabled 3D exploration and more accurate imaging than 2D imaging. The quick entry of CBCT into dentistry due to its low cost

has necessitated the dedication of dental practitioners and academics to researching its potential applications. This review's objective is to provide a brief overview of 3D imaging with CBCT technology, including its fundamental ideas, benefits, and applications in dentistry.[3,4]

Basic Principles

Axial plane slices or a continuous spiral motion across the axial plane are captured by conventional CT equipment utilising a fan-shaped X-ray beam. CBCT is based on a revolving gantry and a stationary X-Ray Source detector. Instead of the slice-by-slice imaging found in traditional CT, a diverging pyramidal or cone-shaped source of ionising radiation is directed through the centre of the region of interest (ROI). Unlike stacked axial slices found in CT, this single scan (rotation) takes planned data (180-1024 2D images, similar to lateral cephalometric images, each one is somewhat offset), significantly lowering the absorbed x-ray dose from 6 to 15 times that of CT. The scanning period of CBCT equipment ranges from roughly 5 to 40 seconds depending on the manufacturer.[5,6]

With a typical working range of 1–15 mA at 90–120 kVp, CBCT has X-ray parameters similar to panoramic radiography, but CT has significantly higher parameters at 120–150 mA and 220 kVp. The computer immediately receives the acquired 2D pictures and reconstructs them into the anatomical volume for 1:1 viewing in the axial, coronal, and sagittal planes using a modified Feldkamp algorithm (orthogonal planes). The information is in the Digital Imaging and Communications in Medicine (DICOM) format, making it simple to communicate with one another and to use with other imaging programmes from outside sources. The ability to interact with the data and produce images that resemble those frequently used in clinical settings is the most practical benefit of CBCT in dental imaging. These recreated images were sequentially evaluated, assessed, and measured for the goal of diagnosis and therapy planning. In addition to basic orthogonal views, the CBCT offers the following display modes, which are described below.[7,8]

Oblique slicing: The isotropic structure of the datasets makes it possible to slice the CBCT images non-orthogonally at any angle to get multiplanar reformations, which are non-axial 2-D planar images (MPR). By cutting over a collection of axial photos, this function generates 2D images at any angle that can be used to assess certain structures (Impacted teeth, TMJ).

Curved slicing: This makes it possible to display a trace view that provides a familiar panorama-like image by tracing the jaw arch. Cross-sectional (oblique coronal) view: With this function, you may choose the thickness and spacing of a series of cross-sectional images that are created successively and perpendicular to the curved slice. Such images are useful for assessing the morphometric properties of alveolar bone for implant placement, the relationship between the third molar that is impacted in the mandible and the mandibular canal, the condylar surface and shape in cases of symptomatic TMJ, or pathological conditions that affect the jaws..

Ray sum: By merging together nearby voxels, this function makes it possible to display the thickened MPR slices. The "ray sum" of the resulting image indicates the precise volume of the patient and can be used to create virtual projections, such as panoramic or cephalometric images that are equivalent to traditional radiographs but without magnification and parallax distortion. Yet, the superimposition of several structures similar to 2D imaging may have a deleterious impact on them..

Volume rendering: With the help of this function, one can visualise volume by only showing certain voxels within a data set. The two most often utilised tools for this job are direct volume rendering and indirect volume rendering. Selecting an arbitrary threshold of voxel values below or over which all grey values are rejected is the process of direct volume rendering. Although there are many methods, maximum intensity projection is the most popular (MIP). (I) shows an image from MIP that includes the voxels with the highest densities within a given thickness. Voxel values below a predetermined threshold are disregarded.

MIP pictures are excellent for finding impacted teeth, evaluating the TMJ, determining the severity of fractures, analysing the craniofacial region, monitoring the healing process after surgery, and spotting soft tissue calcifications. By choosing the density of the voxels to be displayed over the whole data set (referred to as "segmentation"), indirect volume rendering (IVR) creates a volumetric surface reconstruction with depth. It is possible to have two different types of views: transparent views and solid views (surface rendering) (volumetric rendering). The inferior alveolar canal and the mandibular third molar are two examples of relationships between different anatomic elements that may be visualised and analysed using IVR.[9,10]

Applications Of Cbct In Dentistry

In dentistry, radiographic evaluation is crucial for diagnosis and treatment planning. In addition to condensing the three-dimensional anatomy of the radiographed area into a two-dimensional image, 2D imaging has specific inherent constraints (such as magnification, distortion, and superimposition) that collectively result in structural misrepresentation. Several oral and maxillofacial circumstances benefit from the 3D images that CBCT can create. These images can aid in disease diagnosis and severity evaluation, therapy planning and delivery, and follow-up..[11,12]

Cone-Beam Computed Tomography In Oral And Maxillofacial Surgery

3-dimensional imaging is used in oral and maxillofacial surgery (OMS) for many essential tasks. Doctors regularly perform procedures on parts of the face and jaw that cannot be seen clearly before the treatment, running the risk of damaging vital tissues like nerves and blood arteries. Additionally, sophisticated preoperative planning is necessary for complicated surgical operations including orthognathic surgery and the treatment of severe injuries. To guarantee accurate diagnosis and positive clinical outcomes, it is crucial to use imaging techniques that provide detailed information. [11,12]

Dentoalveolar fracture

2-dimensional plain films, including as panoramic, periapical, and occlusal radiographs, are sufficient for the evaluation, treatment planning, and post-operative analysis in many common dentoalveolar treatments. However, in some circumstances, a more thorough 3-dimensional CBCT image is the preferred radiograph, particularly when determining the location of impacted teeth and how they relate to important structures like nerves and bone cortices. Moreover, CBCT provides a more precise representation of problems like root displacement or fragmentation..[13,14]

Impacted Third Molars

The inferior alveolar nerve (IAN), the maxillary sinus, the vasculature, or surrounding soft and hard tissue may be seriously endangered during surgery to remove impacted mandibular and maxillary teeth, especially third molars.[15]

Mandibular Third Molars

The gold standard for first examination of third molars in relation to nearby critical structures has traditionally been panoramic radiography. Rood examined seven radiographic findings in 1990 that were later investigated and further described by other authors and were frequently linked to an elevated risk for IAN impingement or injury. Only three of the radiographic signs—darkening of the roots, deflection of the canal, and interruption of the cortex—were found to be statistically significant. Other radiographic signs include darkening, deflection, or narrowing of the root, dark/bifid apex, cortical interruption, diversion, or narrowing of the canal. When assessing mandibular third molars, a crucial question has been addressed in a number of articles: Is panoramic imaging by itself enough to classify the likelihood of inferior alveolar nerve damage?

Sun et al extensive .'s meta-analysis revealed that although panoramic radiography provides good specificity, its sensitivity is insufficient to completely rule out the possibility of nerve injury. While more recent papers demonstrate the limitations of panoramic imaging in IAN injury prediction, they did not evaluate its sensitivity against CBCT or any other imaging alternative. While panoramic radiographs can detect alarming radiographic indications with high accuracy, their ability to completely rule out the possibility of IAN damage is just passable at best. The doctor can understand the IAN closeness in a vertical, lateral, and depth dimension thanks to CBCT, which offers coronal and sagittal dimensions of the relationship between the IAN and the mandibular third molar. This enables the clinician to assess the probable inter-radicular path of the IAN and measure the precise distance in all dimensions.

Ghaeminia examined the sensitivity and specificity of both imaging modalities and found no appreciable differences between panoramic and CBCT imaging. The IAN might, however, be localised using CBCT in the bucco-lingual dimension. This may ultimately aid to determine surgical strategy and method in cases when it may be placed lingually.[17,18]

Maxillary Third Molars

Due to image distortion and superimposition, panoramic and periapical pictures of impacted maxillary third molars are sometimes insufficient for illustrating their relationship to the maxillary sinus and surrounding tissues. For determining how third molars relate to the maxillary sinus, CBCT has been found to offer a number of important advantages over panoramic and periapical imaging. The buccal roots of the maxillary molars more frequently showed a root projecting into the sinus on CBCT. In some situations, the 2-dimensional picture of panoramic and periapical imaging inherently lacks this important information.[19,20]

Impacted Canines

Impacted maxillary canines frequently pose difficult diagnostic and therapeutic problems. Before choosing a desired treatment strategy and surgical approach for an impacted canine, several characteristics that are all highly variable must be taken into consideration. These characteristics include buccolingual location, tooth angulation in all directions, root dilation, and proximity to or potential resorption of adjacent teeth. Traditionally, to provide numerous views, panoramic imaging was combined with occlusal and periapical films. For pinpointing the precise placement of ectopic maxillary canines, CBCT is more precise than either horizontal or vertical 2-dimensional films. Conventional radiography, particularly on the buccal surfaces of incisors, misses root resorption.. There is a significant difference between 2D and 3D images regarding the width, angulation, and location of the canine, and amount of root resorption of adjacent teeth.[21,22]

Pathology

There are some lesions that can be accurately assessed by CBCT in the wide range of pathology that the head and neck region contains. CBCT provides a clinician with the opportunity to watch development change, recognise borders in a depth perception that may otherwise be challenging to identify, and examine relative approximation of nearby critical structures, in addition to the obvious benefit of analysis in three dimensions. A coincidental finding on panoramic imaging is the presence of pathologic lesions in the jaw. Nonetheless, the clinician must assess whether more imaging is required after a lesion's presence has been established. Based on its relative accuracy in hard tissue, CBCT has strong support in the literature for its 3-dimensional advantages. This is advantageous in certain circumstances where the importance of the lesion's size and nearby anatomy increases..[23,24]

Osteomyelitis and Osteonecrosis

Regardless of the cause, jaw necrosis is characterised by radiographic findings like mottling, sequestra formation, osteosclerosis, osteolysis, dense woven bone, thickened lamina dura, subperiosteal bone deposition, failure of postsurgical remodelling, and if it progresses untreated, pathologic fracture. Non-vital bone that is visible or draining fistulas are examples of clinical findings. Many studies have shown that CBCT imaging is more accurate than panoramic radiographs at displaying radiographic changes. Olutayo evaluated radiographic techniques for identifying osteonecrosis at different stages or levels of severity at initial presentation in the past. While necrosis was extremely low, CBCT was able to accurately assess the extent of bone lesions but panoramic imaging fell short. The authors came to the conclusion that CBCT can more accurately diagnose and describe osteonecrosis and may be more helpful in treating the condition.

Temporomandibular Joint

The gold standard for thorough intra-articular examination of the temporomandibular joint, including disc morphology, position, and movement, as well as the joint capsule, surrounding soft tissues, and musculature, continues to be magnetic resonance imaging (MRI). Although MRI offers a wealth of information, computed tomography still excels at giving a thorough examination of the bony anatomy. Ahmad contrasted PANO, CT, and MRI imaging using osteoarthritis as the study's main focus. The positive percent agreement for PANO was just

19%, but the positive percent agreement for MRI and CT was 59% and 84%, respectively. Consequently, it was determined that tomography was more accurate at predicting condylar bone changes than MRI, which was only useful for analysing the disc's location and joint effusion.

The equivalent benefits to CT and the improved availability of CBCT in the OMS clinic environment may make it beneficial in the diagnosis of jaw osteoarthritis even if this study did not specifically focus on it. When used in conjunction with MRI, CBCT has been demonstrated to increase overall diagnosis accuracy for internal derangement. Mohammed investigated the interpretation of TMJ problems between MRI alone and CBCT in addition to MRI and discovered that CBCT in addition to MRI resulted in higher inter-examiner and intra-examiner consistency than MRI alone.[25,26]

Cone Beam Computed Tomography In Prosthodontics

For a prosthodontist's diverse treatment demands, CBCT offers a special imaging alternative. It can be advantageous in a number of areas of prosthodontic practise, including denture therapy and imaging of the temporomandibular joint for correct movement simulation. The primary benefit of CBCT is its accuracy in determining the true position of the condyle in the fossa, which frequently indicates the likelihood of a disc dislocation in the joint and the degree of translation of the condyle in the fossa. It is more effective because it makes it simple to measure the glenoid fossa's ceiling and makes it possible to see how the condylar head and glenoid fossa relate in three dimensions.[27,28]

Temporomandibular Joint Imaging

The true position of the condyle in the fossa can be determined by CBCT, which frequently discloses the likelihood of a disc dislocation in the joint as well as the degree of translation of the condyle in the fossa. Because of its accuracy, CBCT makes it simple to measure the glenoid fossa's roof and allows users to see how the condylar head and glenoid fossa are related in three dimensions. Because the TMJ's soft tissue calcifications are plainly visible, MRI is not always necessary in these situations.These benefits have made CBCT the imaging method of choice for detecting condylar cortical/sub cortical erosion, cysts, and cases of trauma, discomfort and dysfunction, and fibro osseous ankylosis.[29]

Maxillofacial Prosthodontics

Cone beam computed tomography plays a significant role in the reconstruction of craniofacial defects, on par with standard computed tomography. With the aid of DICOM data software, CBCT can produce three-dimensional augmented virtual models of the patient's face, bony structures, and dentition for use in treatment planning. The widely established digital compatibility (DICOM) protocol was created for data transfer to prevent fraud with little distortion and a true and accurate primary image. With this, the viewer can select any workstation to help with a better comprehension of the task. Prior to the procedure, the graft's shape and placement can be designed virtually, resulting in a virtual restoration of the defect.[30]

Use of CBCT In Managing Endodontic Problems

The use of CBCT in endodontics includes the diagnosis of periapical lesions as a result of pulpal inflammation, the localization of internal and external resorption, the detection of vertical root fractures, the concept of accessory canals, and the identification of the root causes of non-healing endodontically treated teeth. In addition to providing an accurate assessment of current root canal obturations, CBCT can be used to count and characterise the roots and related canals (both main and auxiliary), define working lengths, and identify the kind and degree of root angulation. Also, it has been advised that CBCT be used to determine if the aetiology of the lesion is endodontic or non-endodontic, which could affect the treatment strategy. Due to 2D imaging's lack of superimpositions and projection problems, it is possible to detect horizontal root fractures, vertical root fractures, and the depth of dentin fracture. [31]

Cone Beam Computed Tomography In Implants

In accordance to Dr. P. Branemark's discovery of osseointegration, endosseous dental implants were developed. The accuracy of the diagnostic data regarding the bony structures of the oral region is a key factor in the success of dental implant restorations. This information typically has to be obtained through imaging, which can range from straightforward 2D views, such panoramic radiography, to more intricate views in several planes, depending on the circumstances and the practitioner's level of expertise. By evaluating the existence of any pathology, the location of anatomical characteristics, the location of osseous morphology, and the amount of bone that is available, CBCT can be used for implant planning. CBCT makes it simple to see anatomical features such the inferior alveolar nerve, maxillary sinus, mental foramen, and nearby roots. Also, these particular CBCT pictures enable accurate measurement of volume, area, and distance.

In locations with insufficient bone to support dental implants, CBCT offers a variety of applications.This will make it easier to estimate, before surgery, how much and what kind of transplant material will be required.It aids in learning important details regarding the thickness and perforations of the sinus membrane, the health of the osteomeatal complex, and also in acquiring surgical access to the sinus.[32]

Assessment of ridge morphology

On a two-dimensional imaging technique, it is challenging to evaluate the buccolingual ridge pattern, however CBCT displays the alveolar ridge morphology. A variety of ridge patterns, including irregular ridges, narrow crestal ridge forms, and knife-shaped ridges, can be seen in the photographs. There are visible concavities and cortical bone loss.

Assessment of quality of bone

"Bone quality" is a word that is frequently used and can be found in studies on the success and failure of implants. Skeletal dimensions, bone topologies, the trabeculae's three-dimensional orientation, and bone matrix characteristics all fall under the category of bone quality. Thus, it is a crucial patient-based element in assessing success. Four types of bone quality exist: The four different types of cortical bone are homogeneous cortical bone, thick cortical bone with a marrow cavity, thin cortical bone with dense trabecular bone, and very thin cortical bone with low density trabecular bone, all of which have different strengths. There are additional imaging modalities for a better evaluation of bone quality despite all the CBCT possibilities accessible.[33]

CONCLUSION

The limitations of traditional radiography are attempted to be solved by CBCT and its 3D imaging method. CBCT imaging is a recognised radiographic modality for use in dental treatment planning that is expanding in acceptance and use across the globe. This is partly because of improved knowledge about anatomical landmarks and structures like neurovascular systems that are vulnerable during implant implantation. The popularity of computer-guided surgery, which depends on digital planning based on high-quality CBCT images and may also involve superimposing intraoral and extra-oral face scans to generate a 3D virtual dental patient, is another factor contributing to the growth in the use of CBCT scanning. The reduced radiation dose that propelled this technology into the public eye and made it more effective at diagnosing conditions makes the prosthodontist's demanding workday more calm, simple, and consistently more accurate.

This article supports the notion that CBCT gives the practitioner extra knowledge in a range of clinical situations.Only when conventional radiography is unable to offer pertinent information should the use of CBCT in paediatric patients be taken into consideration.

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