Original Research Paper

Volume - 12 | Issue - 12 | December - 2022 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Prosthodontics

CBCT –THE GOLDEN GLORY OF PROSTHODONTICS: A REVIEW

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ABSTRACT Cone beam computed tomography (CBCT, also referred to as C-arm computed tomography [CT], cone beam volume CT, or flat panel CT) is a medical imaging technique of X-ray CT where the X-rays are divergent,forming a cone. It provides a complete 3D view of the maxilla, mandible, teeth, and supporting structures with relatively high resolution allowing a more accurate diagnosis, treatment planning and monitoring, and analysis of outcomes than conventional 2D images, along with low radiation exposure to the patient. This article is intended to elaborate and enunciate on the various applications and benefits of CBCT, in the realm of maxillofacial prosthodontics, over and beyond its obvious benefits in the rehabilitation of patients with implants. A web-based search for relevant articles in this specific area of interest was also conducted.The selected articles were critically reviewed and the data acquired were systematically compiled.

KEYWORDS : Cone Beam Computed Tomography, resolution, 3D imaging Prosthodontics, X-Ray, Implant Dentistry

INTRODUCTION

The incorporation of the third dimension into dental and craniofacial imaging is now a practical reality. The future of maxillofacial/dental imaging appears exciting as the paradigm shifts from landmarks, lines, and distances to surfaces, area and volumes.

Cone-beam computed tomography (CBCT) is a new medical imaging technique that generates 3-D images at a lower cost and absorbed dose compared with conventional computed tomography(CT).[1] Today, much attention is focused on the clinical applications—diagnosis, treatment and follow-up—of CBCT in the various dental disciplines. An attempt has been made to evaluate probable areas where cone beam computed tomography (CBCT) imaging finds application in prosthodontics, as literature search regarding its direct indications in prosthodontics was inconclusive, apart from those found pertaining to its relevance in implant dentistry. Broadly discussed in this article are areas where CBCT imaging can be applied in the diverse discipline of prosthodontics.

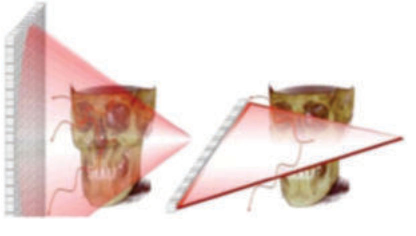

FIG-1

Cone beam computed tomography technology

Cone beam computed tomography scanners are based on volumetric tomography, using a 2D extended digital array providing an area detector. This is combined with a 3D X-ray beam(fig-2). The cone beam technique involves a single 360° scan in which the X-ray source and a reciprocating area detector synchronously move around the patient's head, stabilized with a head holder. At certain degree intervals, single projection images, known as “basis” images are acquired. These are similar to lateral cephalometric radiographic images, each slightly offset from one another.

This series of basis projection images is referred to as the projection data. Software programs incorporating sophisticated algorithms including back-filtered projection are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in three orthogonal planes (axial, sagittal and coronal).[3](fig-3)

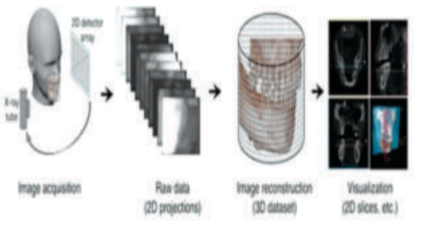

FIG-2

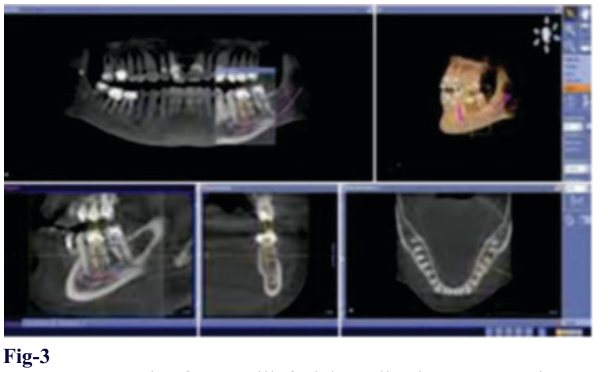

Fig-3

Most CBCT units for maxillofacial applications use an image intensifier tube (IIT). A system employing a flat panel imager (FPI) was released by i-CAT.The FPI–charge coupled device, currently known as FPD, consists of a cesium iodide scintillator applied to a thin film transistor made of amorphous silicon. Images produced with an IIT generally result in more noise than images from an FPD and also need to be preprocessed to reduce geometric distortions inherent in the detector configuration. Hence, most of the currently available CBCT machinery is made with FPD receptors.[4][5]

Application of CBCT in prosthodontics[6,7]

- Implant prosthodontics
- Temporomandibular joint (TMJ) imaging
- Maxillofacial prosthodontics
- Craniofacial and airway analysis
- Comprehensive treatment planning in over denture patients.

Implant prosthodontics

The growing inclination for the selection of dental implants as a viable alternative to replace missing teeth has necessitated a reliable technique capable of obtaining highly accurate measurements to avoid likely damage to vital structures during implant surgery.(fig-4) Anatomic structures such as the inferior alveolar nerve, maxillary sinus, mental foramen, and adjacent roots are easily viewed using CBCT. Further, these specific CBCT images permit precise measurement of distance, area, and volume.[8]

Fig-4

In traditional panoramic radiography, the average machine produces approximately a 1:1.2 ratio magnification, depending on the center of rotation it takes for the particular structure.This must be accounted for when planning implants.

It has been related to find application in pre-surgical imaging, as well as surgical-intra-operative and postsurgical evaluation (for assessment of osseointegration). Furthermore, the availability of newer software to construct surgical guides has further reduced the possibility of structural damage.[9]

To locate the final tooth position under "prosthetically driven implant" technique, a radiopaque marker can be utilized. This data, when arranged on CBCT, can be utilized to create a surgical guide for precise implant placement, which ensures final prosthesis to fit accordingly with the implant alignment.

CBCT has various uses in areas of inadequate bone to support dental implants. This will help in predicting thevolume and type of graft material needed prior to surgery. It assists in gaining valuable information about sinus membrane thickening and perforations, patency of the osteomeatal complex and also in gaining surgical access into the sinus. Therefore, a prosthodontist can avail ample amount of knowledge regarding every detail to perform and improve the success rate of implants in the region of maxillary sinus[9,10].

Assessment of ridge morphology[6]

The buccolingual ridge pattern is difficult to assess on two-dimensional imaging system, but CBCT system presents the alveolar ridge morphology. The images provide the appearance of ridge patterns, such as irregular ridges, narrow crestal ridge form or knife shaped ridges. The loss of cortical bone and associated concavities can be seen. Mc Ginvney et al and Schwartz et al concluded that the 3D images more accurately showed true osseous topography, and considered it a valuable diagnostic aid.

Assessment of quality of bone[6]

The term "bone quality" is commonly used and found in reports on implant success and failure. Bone quality encompasses skeletal sizes, bone architectures, the three-dimensional orientation of the trabeculae, and bone matrix properties. Hence, it is an important patient based factor in determining the success.

Bone quality is of four types:

Type 1: Homogeneous cortical bone;

Type 2: Thick cortical bone with marrow cavity;

Type 3: Thin cortical bone with dense trabecular bone of good strength; and

Type 4: Very thin cortical bone with low density trabecular bone of poor strength.

Even with all the available options in CBCT, there are other imaging modalities for better assessment of the quality of bone.

Temporomandibular joint imaging

One of the major advantages of CBCT is its ability to define the true position of the condyle in the fossa, which often reveals the possibility of dislocation of the disk in the joint and the extent of translation of the condyle in the fossa.(fig-5) Due to its accuracy, CBCT facilitates easy measurement of the roof of the glenoid fossa and provides the ability to visualize the three-dimensional relation that the condylar head has with the glenoid fossa. Soft tissue calcifications around the TMJ are easily visible which reduces the requirement for the use of MRI in such cases.

Due to these advantages, CBCT has become the imaging device of choice in cases of trauma pain and dysfunction, and fibro-osseous ankylosis, as well as in the detection of condylar cortical/sub-cortical erosion, and cysts.[6][11] The use of three-dimensional features facilitates the safe application of the image-guided puncture technique, which is a treatment modality for TMJ disc adhesion. The most recent advance is now in real time imaging, which is used for TMJ movement studies.

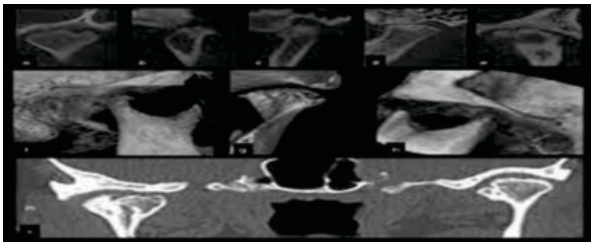

Fig-5

Maxillofacial prosthodontics

Cone beam computed tomography has now replaced the standard CT in imaging and planning craniofacial defect reconstruction. Three-dimensional augmented virtual models of the patient's face, bony structures, and dentition can be created out of CBCT DICOM data by software volume rendering for treatment planning.(fig-6) DICOM or digital compatibility is the universally accepted data transfer protocol developed for rapid, mass data transfer with minimal or nil distortion and nonalterable primary image that helps prevent malpractice. DICOM enables the viewer to work on any workstation.[12]

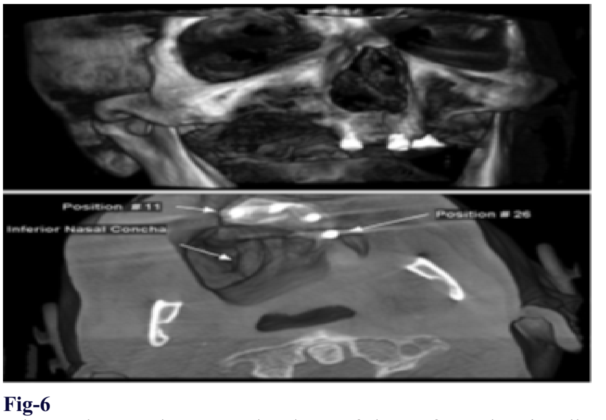

Fig-6

Prior to the actual surgery, the shape of the graft can be virtually planned and can also be positioned in the defect creating a virtual reconstruction of the defect. Also, if required, placement of the implant can be done on the graft accordingly. The challenge is always to find out the area of obstruction in airway. Since many years, several methods have been employed to determine the location of airway, using nasopharyngoscopy, cephalometry, nasal airway resistance, including polysomnography. The use of lateral and frontal radiographs to assess the pharyngeal airway has also been found to be useful.[13,14,15] Obturators for cleft closures can be precisely milled in larger CAD/CAM units, thereby eliminating the entire cumbersome clinical process of obturator construction.

Craniofacial and airway analysis

Identifying the area of airway obstruction has often proved to be challenging. During the past few decades, various methods have been used to evaluate the airway, including nasopharyngoscopy, cephalometry, nasal airway resistance, as well as polysomnography. Lateral and frontal radiographs have been used to assess the pharyngeal airway. CBCT offers a three-dimensional presentation of the airway and its surrounding structures which makes volumetric analysis and accurate visualization of the airway possible. By using

CBCT scans to analyze the complex airway anatomy,(fig-7) previous studies have confirmed that volumetric measurement of airways utilizing CBCT are accurate and with minimal error, thus offering an increased view of both untreated obstruction tendencies and potential changes in the airway through treatment modality. Three-dimensional imaging is a very efficient method to inspect and identify diffuse narrowing or focal narrowing (encroachments) of the airway.[16]

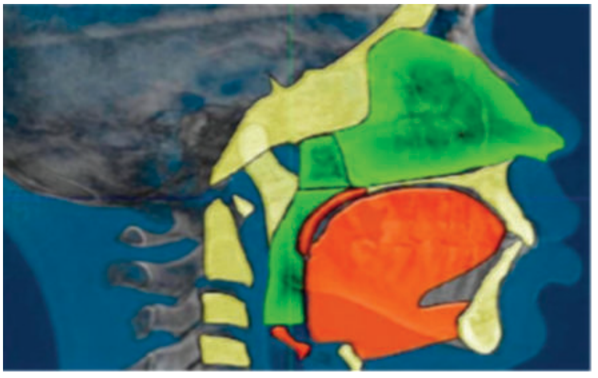

Fig-7 Comprehensive treatment planning in overdenture patients(fig-8)

The idea of retaining some teeth/roots for over denture rehabilitation is not new. It was first described over 150 years ago[17][18]. It was found by clinicians in the 1950s, that when teeth were extracted, there was continuous resorption of alveolar bone because of which very less support was left for complete dentures making them difficult to wear.[19,20,21]

Analysis of several longitudinal studies of edentulous patients wearing complete dentures found that the resorption was progressive, irreversible, and cumulative.The rate of resorption was greatest in the first 6 months after the extraction of the teeth, but the rate varied and was affected by a variety of biological and mechanical factors. However, the rate of resorption in the mandible was 4 times than that of the maxilla, as described by Tallagren, who found that after 25 years of denture wear, the average bone loss in the mandible was 9–10 mm of vertical height compared to 2.5–3 mm on the maxilla. This process of initial assessment to a follow-up during a 4 years review would be precise with the use of a CBCT, thereby improving the prognosis of such dentures. [22][23]

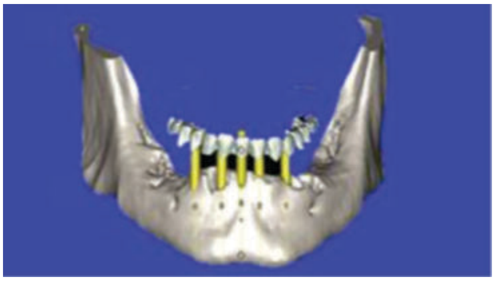

Fig-8

Limitations of CBCT[24,25]

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 artefacts, noise and poor soft tissue contrast. An artefact 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. Artefacts can be due to beam hardening, patient related artefacts, scanner-related artefacts and cone-beam related artefacts.

Image noise is because of the major volume being irradiated during CBCT scanning resulting in heavy interactions with tissue 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. CBCT units have less soft tissue contrast than conventional CT machines. Three factors which limit the contrast resolution of CBCT are as follows:

1. Increased image noise
2. The divergence of the x-ray beam and
3. Numerous inherent flat-panel detector-based artefacts

Summary

CBCT imaging is a well-established radiographic modality in treatment planning ,becoming increasingly popular and hence is being globally used in oral health care. The increased diagnostic capability combined with the lower radiation dose will also help bring this technology into the limelight. Undoubtedly, future developments in CBCT technology will result in systems with even more favorable diagnostic yields. The applications described herein are merely the humble beginnings of a much more elaborate and versatile imaging modality, which will provide an valuable user interface with associated machinery and thus transform the pressing work schedule of a prosthodontist into a relaxed, easier, and reliably more precise one.

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