Cone Beam Computed Tomography in Prosthodontics

Mohamed Abdulcader Riyaz[1], Mohammed Suleman Al-Ruthea[2]

ABSTRACT

Cone beam computed tomography (CBCT) is called as C-arm computed tomography, cone beam volume CT, or flat panel CT. It is an imaging technique in the field of dentistry in which the X-rays are divergent, leading to the formation of cone shaped beam. The system of CBCT has been designed for imaging primarily the hard tissues of the maxillofacial region. It contributes to accurate and effective treatment planning for the patient. The increasing demand of this technology provides the dental clinician with an imaging modality capable of providing a three-dimensional view of the maxillofacial skeleton with least distortion. CBCT provides a unique imaging option for various treatment needs of a prosthodontist. It can prove to be beneficial in various aspects of prosthodontic practice i.e. from imaging of the temporomandibular joint for accurate movement simulation, to denture therapy. CBCT could play an important role in reduction of hectic routine for the clinician. Therefore, the aim of this article is to specify the applications of CBCT in the field of prosthodontics along with the benefits and limitations of CBCT.

Keywords: Cone Beam Computed Tomography, Prosthodontics, X-Ray, Implant Dentistry

INTRODUCTION

The development of computed tomography in 1972, which was reported in 1973, enabled conditions to be diagnosed with 3-dimensional images. These devices were used in many fields, and their use in dentistry became more frequent with the advent of implant surgery. Arai and colleagues set out to develop a compact CT apparatus specifically for use in dentistry. In 1997, they created a prototype-limited cone beam CT (CBCT) device for dental use that was dubbed Ortho-CT. In about 2 years after that achievement, that device was used in approximately 2000 cases to evaluate conditions, such as impacted teeth, apical lesions and mandibular and maxillary diseases, both before and after surgery in the Department of Radiology at the Nihon University School of Dentistry Dental Hospital, proving highly successful.[1]

It is that imaging technique where the X-rays are divergent, forming a cone shaped beam. An effort has been made to evaluate specific areas where cone beam imaging can be applied in prosthodontics. There is not so much literature search has been done regarding the direct applications in prosthodontics except relevance in implant dentistry.[1,2]

For most specialty practitioners, the use of advanced CT imaging has been limited by the cost, its availability and considerations in radiation dosage. However, the introduction of cone beam computed tomography (CBCT) for the maxillofacial region provides a new opportunity to request for multiplanar imaging. Many prosthodontics are familiar with the thin-slice images produced in the axial plane by conventional helical fan beam CTs. It allows the creation of "real-time" images not only in the axial plane but also two-dimensional (2D) images in the coronal, sagittal and even oblique or curved image planes. This process is referred to as multiplanar reformatting (MPR).[2,3]

The most important advantage of CBCT is that it correctly identifies 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. It has a higher efficacy because of which it allows the 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.[4]

The CBCT has become the choice in cases of trauma, pain, dysfunction, fibro-osseous ankylosis, as well as in the detection of condylar cortical/sub-cortical erosion, and cysts because of several advantages. CBCT uses an extra oral imaging scanner, specifically designed for head and neck imaging that produces 3D scans of the maxillofacial skeleton. The unit of CBCT has a size equal to conventional panoramic radiographic machine.[2,5]

Cone beam machines use x-rays in the form of a large cone covering the head surface to be examined; instead of a linear array of detectors as in CT, a 2-dimensional (2D) planar detector is used. Most prosthodontists are familiar with the thin-slice images produced in the axial plane by conventional helical fan beam CTs. CBCT allows the creation of "real-time" images not only in the axial plane but also two-dimensional (2D) images in the coronal, sagittal and even oblique or curved image planes - a process referred to as multiplanar reformatting (MPR) (Figure-1,2). Furthermore, CBCT data are susceptible to reformation in volume, rather than a slice, providing three-dimensional (3D) information.[2,5,6] Therefore, the main aim of this article was to sensitize the prosthodontist to CBCT technology, provide an overview of the unique image display capabilities

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of currently available maxillofacial CBCT systems and to define the specific application of various CBCT display modes to clinical prosthodontic practice.

Applications of CBCT in Prosthodontics[2,7]

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

Implant prosthodontics

Endosseous dental implants were introduced following the discovery of osseointegration by Dr P. Branemark. The success of dental implant restorations depends, in part, on adequate diagnostic information about bony structures of the oral region. Acquiring this information usually requires some form of imaging, which may vary from simple 2D views, such as panoramic radiographs, to more complex views in multiple planes, depending on the case and the experience of the practitioner.[1,2,8]

Implant planning can be done with CBCT by assessing the presence of some kind of pathology, location of anatomic features, location of osseous morphology and amount of bone available. Anatomic structures such as the inferior alveolar nerve, maxillary sinus, mental foramen, and adjacent roots are easily viewed using CBCT. In addition, these specific CBCT images also permit precise measurement of distance, area, and volume.[9]

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.

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.[1,2,5]

CBCT has various uses in areas of inadequate bone to support dental implants. This will help in predicting the

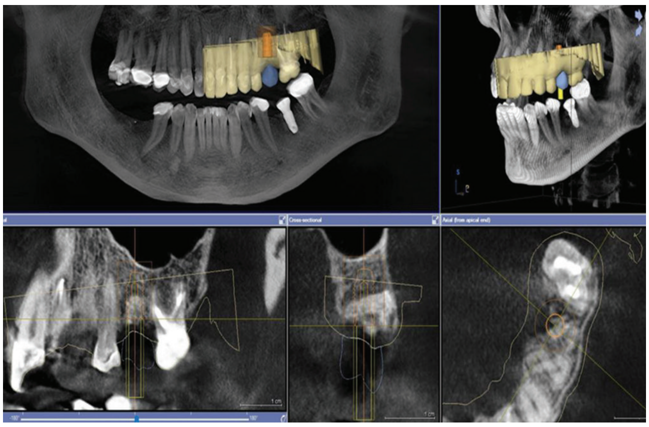

Figure-1: Shows various views of cone beam computed tomography used in implant planning

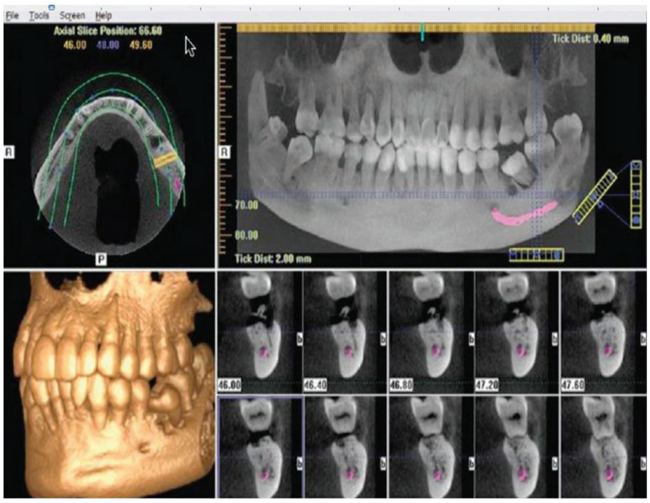

Figure-2: Shows various sections of cone beam computed tomography

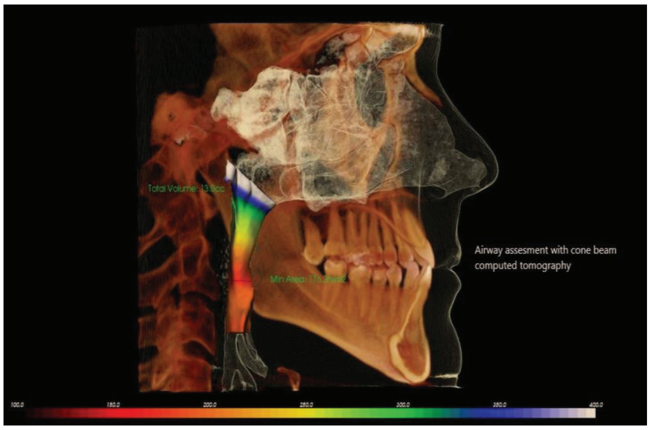

Figure-3: Airway analysis using CBCT

Figure-4: CBCT in Planning of Overdentures.

volume 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.[2,1,10]

Assessment of ridge morphology[2]

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[2]

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. 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.[2,11,12]

MAXILLOFACIAL PROSTHODONTICS

In craniofacial defect reconstruction, cone beam computed tomography has a major role which is equal to the standard computed tomography. CBCT can create three-dimensional augmented virtual models in treatment planning of the patient's face, bony structures, and dentition with the help of DICOM data software. This digital compatibility (DICOM) is the globally accepted protocol developed for transfer of data to prevent malpractice with minimal distortion and correct and actual primary image. With this, any workstation can be chosen by viewer to aid in better understanding of the work.

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.

To perform accurate volumetric analysis, three-dimensional representation of the airway along with the surrounding structures is also possible with the help of CBCT. With the use of CBCT scans, the analysis of the anatomy of complex airway (figure-3), are found to be accurate which is confirmed from the previous studies. The volumetric measurement of airways utilizing CBCT is found to be accurate with least error. Hence, three-dimensional imaging is a very productive method to examine encroachments and monitor the diffuse narrowing or focal narrowing of the airway.[13,14,15]

COMPREHENSIVE TREATMENT PLANNING IN OVERDENTURE PATIENTS

For over denture rehabilitation, the concept of retaining teeth/roots is described 150 years ago. 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 (figure-4).

It was found from the previous longitudinal studies that, edentulous patients who were wearing complete dentures since long time, the resorption of bone was severe, progressive and cumulative. In the first 6 months after the extraction of the teeth, the rate of resorption was highest but the variations were seen due to various biological and mechanical factors. However, the rate of resorption in the mandible was found to be 4 times than that of the maxilla. The reason was adopted from the previous studies which was 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. CBCT can be utilised along with various third party softwares in the meticulous planning of overdentures improving its prognosis.[16,17,18]

Advantages of CBCT over CT

High radiation dose, cost, availability, longer scanning time have led to restricted use of CT in dentistry. Few of these problems can be overcome with CBCT, which provides a number of potential advantages for oral and maxillofacial imaging, compared with conventional CT.

- It is relatively inexpensive than traditional Medical CT
- The weight of this device is light and size is small
- The resolution of CBCT is better i.e. with smaller pixels
- There is no need for special electricity requirements.
- They are wall mounted therefore, there is no need of floor strengthening
- Manpower is also reduced as it is easy to operate and no technician training is required as cone beam manufacturers and vendors helps in understanding of the method to the dentist which makes the work easier
- Mostly, the patient is seated due to the open design in

CBCT when compared with medical CT unit which reduces the claustrophobia and greatly enhances patient comfort and acceptance

- The dose of the radiation is reduced when compared with medical CT
- The protocol selection is at times not easier with CT in comparison to CBCT, for example, slice thickness.
- Artefacts related to metals are much lesser in the CBCT when compared to the CT because of which the use of localization markers for precision marking is possible.
- The first use of CBCT in the facial region is for implant planning and CBCT scores much higher in all aspects when compared to the traditional medical CT.
- Finally, the CBCT is superior to CT in the imaging of facial skeleton (due to the complex nature of the anatomy and the machine design) while in all other regions CT may have the edge.[2,10]

Limitations of CBCT[19,20]

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

CONCLUSION

CBCT imaging is a well-established radiographic modality in treatment planning for dental implants, becoming increasingly popular and globally used in oral health care. This is partially due to new insights into anatomic landmarks, and structures at risk during implant placement such as neurovascular structures. Another reason for the growing use of CBCT scanning is the increasing popularity of computer-guided surgery that relies on digital planning based on high-quality CBCT images but may also include the superimposition of intraoral scans and extra-oral face scans to create a 3D virtual dental patient. The efficacy of diagnostic capability is much higher with the lower radiation dose which helped this technology into the limelight and thus transforming the pressing work schedule of a prosthodontist into a relaxed, easier, and reliably more precise one.

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