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CBCT in Prosthodontics

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Abstract

Background: CBCT specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift from a 2D to a 3D approach to data acquisition and image reconstruction. While Cone beam computerized tomography (CBCT) was developed in the **1990s** as an evolutionary process resulting from the demand for three-dimensional (3D) information obtained by conventional computerized tomography (CT) scans. Computerized tomography is the technique which gives numerous advantages over the traditional graphic methods. Benefits of this technique are further enlightened when a cone beam computerized technique introduced has application in dental practice mainly. CBCT systems have been designed for imaging hard tissues of the maxillofacial region. The increasing availability of this technology provides the dental technician with an image modality capable of providing a three dimensional representation of the maxillofacial skeleton with minimal distortion.

Aim: CBCT could play a crucial role in lessening the burden of hectic Prosthodontics routine for the clinician and critically contribute to accurate and effective treatment for the patient.

Conclusion: Although CBCT equipment has existed for a quarter of a century, only over the past decade has it become possible to produce clinical systems that are both inexpensive and small enough to be used.

Clinical significance- CBCT is a 21st century modality and it offers an accurate one-to-one measurement that can be made on the images and transferred directly to the surgical field.

Keywords: Cone beam computerized tomography, computerized tomography, Maxillofacial, Prosthodontics.

Introduction

Although nothing can replace history and physical examination when evaluating patients, the use and evolution of non-invasive technology for imaging areas not visible to the human eye has become a bigger part of the diagnostic process .[1] Dental imaging has advanced rapidly over the last years. Static projectional images were relied upon for diagnosis in the maxillofacial region, but we are moving toward digital, three-dimensional (3D) and interactive imaging applications. Much of this movement is attributed to a recently introduced CT technology known as ''cone-beam computed tomography'' or ''digital volume tomography.'' This technology has offered dentists a view of all angles of areas of concern. This technology has been embraced quickly by the dental profession. It is considered as ''what was missing'' by many in the field.

3D imaging has improved diagnostic efficiency and the practice of dentistry in a variety of ways; from routine evaluation to complex analysis of unusual pathology and congenital deformities, the technology available today makes dentistry better, and easier, and more accurate. At the same time, a plethora of applications have been developed that use the three dimensional data for a variety of tasks: implant planning, surgical navigation, orthodontic applications, and more. All of this is for the benefit of patients.[1]

CBCT can eliminate the projection inaccuracies inherent in 2D cephalograms, and can further provide accurate assessment of the craniofacial structures in three dimensions with exposure sequences that are shorter than those for standard panoramic radiography, and only several times greater in dose than for one such image. The volume that is recorded can be used to simulate multiple plain and tomographic projections.[2]

Historical Background

Intraoral radiography was first used within weeks of the discovery of X rays by **Roentgen in 1895**. Extra oral imaging, including cephalometric radiography, followed soon thereafter.[3]

In 1930 approximately 36 years after the discovery of X-ray by roentgen in 1895 **Broadbent** introduced cephalometry in dentistry. **Broadbent (1931)** used radiographs to record the 3D nature of the head using a combination of lateral and antero-posterior radiographs.[4,5]

The panoramic radiograph was first proposed and experimented with in the **1930 by Dr. H. Numata** of Japan, in the mid-1940s , the father of panoramic radiography,Dr. Yrjo Veli Paatero of Finland , refined the panoramic technique.[6]

In 1940s and 1950s , orthodontists began to relay on the lateral cephalometric radiograph as a diagnostic aid , and diagnostic ability was confined to 2 -dimension. The introduction of panoramic radiography in the **1960s** and its widespread adoption in **1970s and 1980s** heralded major progress in dental radiology, providing clinicians with a single comprehensive image of jaws and maxillofacial structures. **Even so, 2D views have limitations;** Geometric, rotational, & head positioning error mean that the anatomy is not accurately represented; some elements can be obscured; &calibrating the views is a problem.[7]

Computerized tomography[8] was developed by Sir Godfrey Hounsfield in 1967 who later shared the Nobel Prize in Medicine with Allan Cormack, developer of the mathematical algorithms for reconstruction of the data and since the first prototype, there has been a gradual evolution to five generations of such systems.

Application of CBCT In Prosthodontics

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. 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.[2] 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. Preliminary studies on CBCT have concluded that the CBCT image underestimates the actual distance. However, these differences were significant only for the skull base. Imaging of the dental and maxillofacial regions were found to be quite accurate as the voxels exhibit a sense of "isotropism" that is, uniformity in all dimensions, demonstrating no significant differences.

The fact that measurements from the CBCT are routinely accurate throughout the maxilla and mandible makes this an excellent imaging modality for planning implant placement.[3] Using these features, an implantologist can gain confidence in treatment planning for complex surgical procedures such as sinus lift and ridge augmentation, apart from gaining a secure sense during intricate extraction procedures and implant placement – with or without a surgical guide. The surgical guide can be fabricated with a CBCT image, in the complete absence of the patient (thereby reducing the number of patient appointments), thus, allowing precise placement of implants, prefabrication of the abutments and prosthesis, and "same day" delivery of the prosthesis. Computed tomography (CT) images also have similar capabilities, but the benefit of CBCT is less radiation exposure to the patient and greater image accuracy. Cone beam computed tomography imaging also finds application in presurgical 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.[4] CBCT data combined with data from intraoral scanners like the Cerec Omnicam® or Cerec Bluecam® (Sirona, Germany) is used to interface with other interactive machinery like CAD/CAM[5] or three-dimensional printers for precision milling/additive manufacturing resulting in immediate delivery of chair side fixed prostheses and surgical guides.[6] In the "prosthetically driven implant" technique, a radiopaque marker (barium coated teeth) can be utilized to demarcate the final tooth position. This data, when aligned on CBCT, can be utilized to create a surgical guide for precise implant placement, which ensures final prosthesis to implant alignment.[7] Cone beam computed tomography can be extremely helpful in identifying areas of inadequate bone to support dental implants. This information would allow in determining the volume of graft needed prior to surgery and the type of graft material to select. Heiland et al. described the intra-operative use of CBCT in two cases to guide the insertion of the implant after microsurgical bone transfer.[8,9] Postgraft imaging would reveal the amount of bone formed and will also provide information on bone density. Cone beam computed tomography provides valuable information about the thickening and perforations involving the sinus membrane, patency of the osteomeatal complex and also aids in more informed planning with respect to surgical access into the sinus.

This confirms that the range of anatomical detail gained through a CBCT provides the implantologist ample amount of information to improve the success rate of grafting of the maxillary sinus and sinus implants. Figure 1a-c demonstrate the improved visualization and comprehension of the sinus anatomy in the area in which the implants were placed.

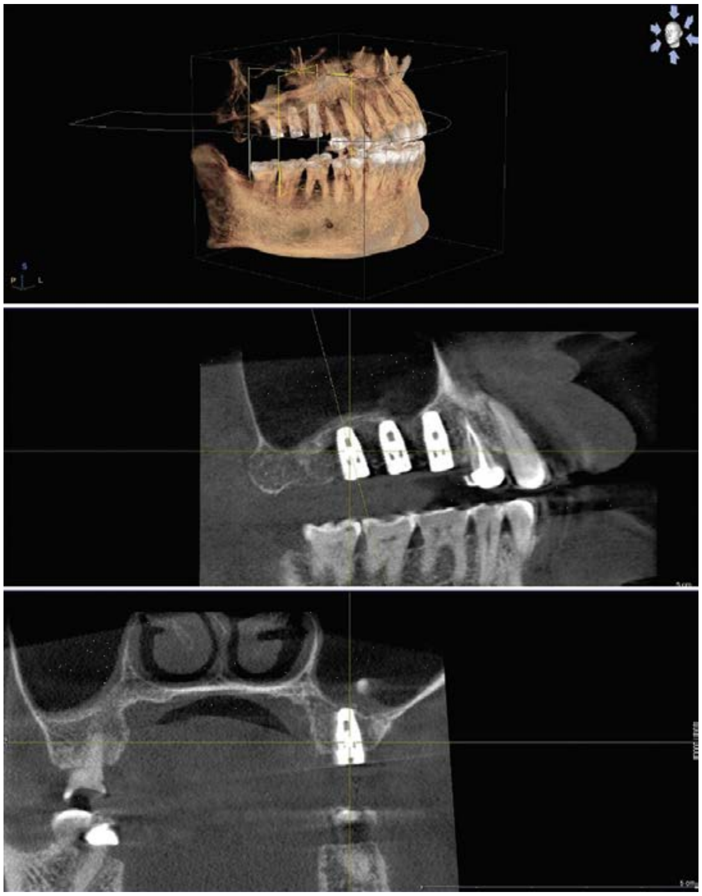

Figure 1: (a) Three-dimensional view of three implants in the right maxillary posterior region; GALAXIS GALILEOS viewer 1.9 software in SIRONA ORTHOPHOS XG 3D, permits the image to be viewed in all directions/probable angles, demonstrating the proximity to important vital structures. (b) The same three implants in a tangential view. (c) Cross-sectional view showing relationship of implant to the floor of the maxillary sinus.

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.[10] 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.[11] Due to these advantages, CBCT has become the imaging device of choice in cases of trauma [Figure 2a and b], pain and dysfunction, and fibro-osseous ankylosis, as well as in the detection of condylar cortical/sub-cortical erosion, and cysts.[12] 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.[13, 14]

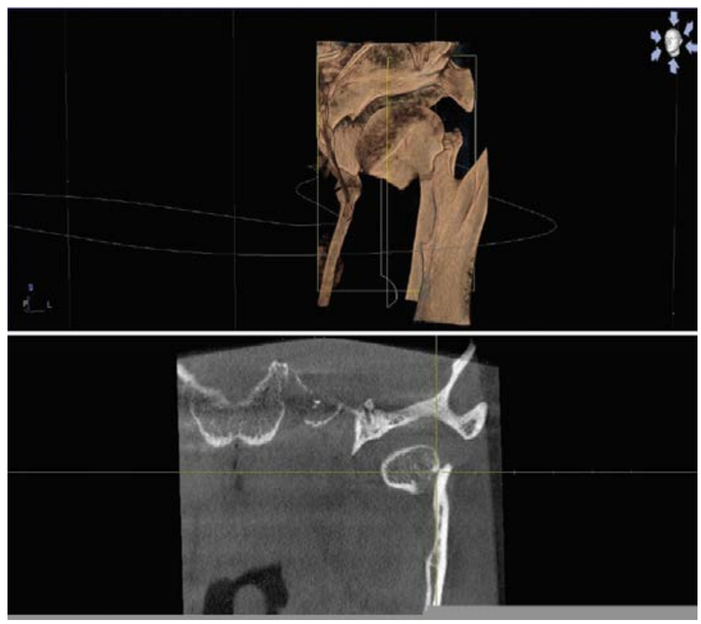

Figure 2: (a) Three-dimensional view of the fractured head of a condyle. The image also demonstrates the glenoid fossa, styloid process, and medial aspect of the mandibular ramus. (b) Cross-sectional view of the fractured condylar head

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. DICOM or digital compatibility is the universally accepted data transfer protocol developed for rapid, mass data transfer with minimal or nil distortion and non-alterable primary image that helps prevent malpractice. DICOM enables the viewer to work on any workstation. The shape of the graft can be virtually planned and can also be positioned in the defect creating a virtual reconstruction of the defect prior to the actual surgery. In addition, implant placement (if required) onto the graft can also be planned.[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 [Figure 3] which makes volumetric analysis and accurate visualization of the airway possible. By using CBCT scans to analyze the complex airway anatomy, 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]

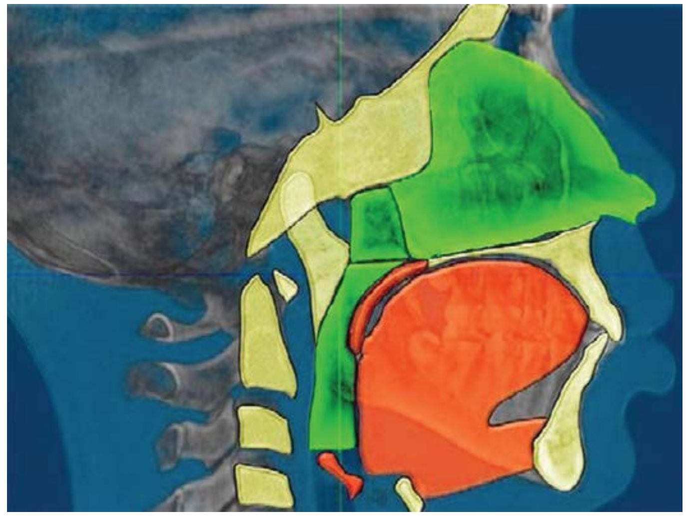

Figure 3: Airway zones (green) divided into nasal, nasopharyngeal, and oral airways; supported posteriorly by the spine, superiorly by the cranial base, and anteriorly by the maxilla, mandible and hyoid (cream). Mobile elements associated with airway – tongue, soft palate, and epiglottis (orange).

Comprehensive Treatment Planning In Overdenture Patients

In the 1950s, clinicians noted that when teeth were extracted, the residual alveolar bone was in a continual state of resorption, which left very little support for complete dentures, thus making them difficult to wear. Analysis of several longitudinal studies[17, 18] of edentulous patients wearing complete dentures found that the resorption was progressive, irreversible, and cumulative.[18] 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.[18] However, the rate of resorption in the mandible was 4 times than that of the maxilla, as described by Tallagren,[18] 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.

Medico legal Issues Related To CBCT

1. Purchasing and Ownership of a CBCT Machine:- Use of CBCT in diagnosis and treatment, a purely "medical" issue, the advent of CBCT has raised a number of medico legal questions, among them issues of ownership, the image volume to be covered, interpretation, and licensure. some states allow even non-dentists to own and operate CBCT machines, while in others the laws make it difficult and sometimes practically impossible, due to the certificates of need (CON), for many fully licensed dentists or even radiologists to acquire a CBCT machine. Whether only radiologists, medical or oral and maxillofacial, should be allowed to own and operate CBCT machines is an issue that has been raised.

2. The Field of View: - The rationale for this is to protect both the individual patient's and the public health from unnecessary radiation. In principle, the anatomical area covered by a CT scan should be no different than would have been covered by a plain-film examination. The extent of the examination should be based on the patient's symptoms and the findings on clinical examination.

3. Responsibility for Interpreting CT Images: - Major reason that is emerging as a barrier to acquiring a machine relates to liability of interpreting the images. Facilities such as dental x-ray laboratories and medical radiology facilities, including hospitals that do so-called dental CT scans (eg, for implant planning, to locate an impacted tooth or for orthodontic purposes), do not read and write a report of the case. In fact, medical facilities typically include a specific disclaimer states: "These images were NOT reviewed by radiologist for diagnostic purposes, and NO radiological review, report, or professional bill was generated. These images are intended for review by dental care professionals to aid in dental implant or extraction surgical planning. No diagnostic claims regarding these images. If there are concerns regarding pathology and a radiological consult is desired, please contact related pathologist and radiologist.

4. Issues Related to Referring Out the Interpretation of CT Scans:-It is probably fair to state that, with the exception of individuals who have completed a formal program in oral and maxillofacial radiology, most orthodontists, and dentists in general, do not have the expertise to interpret CT scans, nor do they feel comfortable doing so. Thus, they are obligated to refer the reading of the images. From the referring dentist's perspective, no special software is required. If the dentist uploads the raw data in Digital Imaging and Communications in Medicine (DICOM) format, the radiologist can view the case using any number of commercially available software packages. DICOM is a standard developed by American College of Radiology–National Electrical Manufacturer's Association (ACR-NEMA) for communications between medical imaging devices. Once he has read the case, the radiologist writes a report and sends it in one of the aforementioned ways or uploads it to the FTP server from which the dentist downloads it.

Informed Consent : Cone Beam CT Scan

1. A CBCT scan, also known as Cone Beam Computerized Tomography, is an x-ray technique that produces 3D images of your skull that allows visualization of internal bony structures in cross section rather than as overlapping images typically produced by conventional x-ray exams. CBCT scans are primarily used to visualize bony structures, such as teeth and your jaws, not soft tissue such as your tongue or gums.

2. Advantages of a CBCT Scan over conventional x-rays: A conventional x-ray of your mouth limits your dentist to a two-dimensional or 2D visualization. Diagnosis and treatment planning can require a more complete

understanding of complex three-dimensional or 3D anatomy. CBCT examinations provide a wealth of 3D information which may be used when planning for dental implants, surgical extractions, maxillofacial surgery, and advanced dental restorative procedures. Benefits of CBCT scans include: A. Higher accuracy when planning implant placement surgery; B. Greater chance for diagnosing conditions such as vertical root fractures that can be missed on conventional x-ray films; C. Greater chance of providing images and information which may result in the patient avoiding unnecessary dental treatment; D. Better diagnosis of third molar (wisdom teeth) positioning in proximity to vital structures such as nerves and blood vessels prior to removal; E. The CBCT scan enhances your dentist's ability to see what needs to be done before treatment is started.

3. Radiation: CBCT scans, like conventional x-rays, expose you to radiation. The amount of radiation you will be exposed to is the equivalent to what you would receive from several days in the sun. The dose of radiation used for CBCT examinations are carefully controlled to ensure the smallest possible amount is used that will still give a useful result. However, all radiation exposure is linked with a slightly higher risk of developing cancer. But the advantages of the CBCT scan outweigh this disadvantage.

4. Pregnancy: Women who are pregnant should not undergo a CBCT scan due to the potential danger to the fetus. Please tell the dentist if you are pregnant or planning to become pregnant.

5. Diagnosis of non-dental conditions: While parts of your anatomy beyond your mouth and jaw may be evident from the scan, your dentist may not be qualified to diagnose conditions that may be present in those areas. If any abnormalities, asymmetries, or common pathologic conditions are noted upon the CBCT scan, it may become necessary to send the scan to an Oral and Maxillofacial Radiologist for further diagnosis. If this occurs, we will discuss this option with you as well as the fee for the additional diagnosis and referral.

Please Do Not Sign This Form Unless You Have Read It, Understand It, And Agree To Accept The Risks And Advantages Noted.

I, being 18 years or older, certify that I have read the above statement. I understand the procedure to be used and its benefits, risks, and alternatives. I acknowledge that I have had a full opportunity to discuss the matter with doctor and I have been given the opportunity to have my questions answered, and accept the risks of the CBCT scanning procedure as described above. I therefore give my consent to have "CBCT centre" and his staff as he may designate, perform a CBCT scan.

Signature of Patient, or Legal Guardia

Witness to Signature

Summary

Cone beam computed tomography (CBCT) is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex. CBCT uses radiation in a similar manner as does conventional diagnostic imaging and reformats the raw data into Digital Imaging and Communications in Medicine (DICOM) data. DICOM data are imported into viewing software that enables the manipulation of multiplanar reconstructed slices and three-dimensional volume renderings. DICOM data also may be used in third-party software to aid in dental implant placement, orthognathic surgery and orthodontic assessment.[19]

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