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CLINICAL APPLICATIONS OF CONE BEAM IMAGING IN DENTISTRY - A REVIEW

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ABSTRACT

For optimal treatment planning, a meticulous diagnosis is the need of hour. This article focuses on the role of cone beam computerized tomography (CBCT), an imaging modality which offers many advantages by combining conventional x-rays with computerized volumetric reconstruction to reproduce a 3-dimensional image. A search of the peer-reviewed and indexed dental literature on CBCT was performed to determine its clinical applications in dentistry. This article presents a review on the clinical applications of CBCT imaging modality in Dentistry.

INTRODUCTION

The advent of Cone Beam Computerized Tomography (CBCT) in the field of dentistry has started a revolution in oral and maxillofacial imaging, and out shadowing the role of panoramic radiography of late 1960's. The commercial CBCT started in 1999 in Europe. Since then, this new technology especially in dentistry has expanded several folds in terms of its manufacturing centers and its clinical applications [1].

More than dozen commercial CBCT systems are now available currently. The purpose of this article is to outline various concepts of CBCT technology, hence help the practitioners towards the understanding of its technical considerations and viewing the image thus providing clinical guidance on the appropriate use of this modality in dental practice.

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Principles of CBCT Imaging [2]: The mechanics of CBCT imaging comprises of two phases;

1) Reconstruction phase. Software programs are applied to projection data to generate a three-dimensional (3D) volumetric data set composed of cuboidal volume elements (voxels). The default presentation of the data set is usually as a series of contiguous images in three right angle planes (axial, sagittal and coronal).

2) Acquisition phase. A pyramidal or cone shaped x-ray beam is directed towards an area x-ray detector on the opposite side of the patient's head and multiple exposures are made during a single full or partial synchronous rotation. The resultant series of two-dimensional (2D) projections or basis images form a set referred to as the projection data.

CBCT Technique vs. Panoramic Radiology Technique: **S**imilarities exist between panoramic radiography & CBCT. However, there are also a number of important distinctions between the two techniques, the most important being the greater number of technique parameters available for CBCT imaging.

1) TECHNICAL PARAMETERS: Two parameters need to be adjusted when performing a CBCT scan; the tube current and tube voltage. These two factors control the quantity and quality of x-ray photons generated by the tube head. They have a direct influence on the dose of radiation & quality of image being received by the patient. If adjustment of these parameters is done then it can provide a significant reduction in radiation dose without even compromising the image quality. In contrast with panoramic radiography, CBCT units also allow some additional modifications of scan parameters that may influence the quality of image and hence affect patient dose. These include:

A. *Field of View (FOV)* [3] - The tissue volume of the patient's head exposed during imaging is referred to as the FOV. An adjustable FOV, particularly in large units, is desirable as x-ray exposure should be limited to cover only the region of interest. This provides marked reduction in patient radiation exposure compared to panoramic radiology.

B. *Projection data* - The total number of basis images comprising the projection data of a single scan may be fixed or variable. This is usually reflected in the selection of scan time. While increasing scan time provides more basis images, and produces "smoother", less grainy images, this is usually accomplished at a higher patient radiation dose.

C. *Scan arc* - Many CBCT imaging systems employ a complete circular (3600) trajectory; however some use a limited, or even a variable, scan arc. A limited or variable arc reduces the scan time and is mechanically easier to perform, however data must be extrapolated to provide a full volumetric dataset. The effect, if any, on diagnostic image quality or radiation dose is currently unreported.

D. *Spatial resolution* - While nominal resolution for CBCT units is equipment specific (range: 0.076mm to 0.4mm), the resolution of some CBCT units can be varied at the reconstruction phase using a process of pixel binning (the gathering and combining of information from adjacent regions). This can substantially reduce file size and therefore reconstruction time. Resultant images have reduced resolution but improved image contrast. Higher resolution settings may not be clinically important as patient motion may be the limiting factor in CBCT resolution.

2) PATIENT POSITIONING [4]: The patient's head must be firmly stabilized, whether they are standing, lying or seated, during the entire scan when obtaining a CBCT image. This reduces the potential for motion during the scan, a significant source of reduced image quality.5 Stabilization can be accomplished using equipment such as chin rests and/or head holders and providing adequate instructions to the patient prior to exposure to remain still during the procedure and to keep the teeth closed either together or on a bite block.

3) PATIENT PROTECTION: The patient should be draped in a lead torso apron to reduce exposure to scatter radiation during the obtainment of both CBCT and panoramic

4) EXPOSURE ADJUSTMENT: Because CBCT exposes the head in one rotational scan, acquisition time is comparable to that of panoramic radiography. However CBCT imaging also incorporates correction and further computational processes on the original projection images. The time for data set reconstruction can be much longer than the scan time and may range from 30 seconds up to several minutes. Image correction necessitates routine calibration of the digital detector, referred to as image calibration, to prevent untoward artifacts affecting image quality.

5) IMAGE VIEWING: Unlike panoramic radiography, CBCT units provide a sequential "stacked" set of coronal, sagittal and axial orthogonal images. These images are not inherently easy to interpret. Viewing CBCT images, unlike panoramic images, is performed as an interactive process – windowing and leveling, changing the brightness and contrast, reorienting, rotating or reslicing the volume in all directions may be used by the operator to adapt the final image to his/her diagnostic objectives.

Relative Radiation Exposure: The type and model of CBCT device as well as the scan parameters used (particularly FOV) markedly influence the radiation dose to the patient. CBCT provides an equivalent dose of 3 to 44 times that of a single panoramic radiograph, or between 8 to 131 days of background radiation [5]. While smaller FOV units should reduce radiation exposure, some actually produce far greater patient exposure because they have tube heads producing continuous radiation exposure.

IMAGING TECHNIQUES:

1) Multi-planar Reformation (MPR): This technique creates non-axial 2D images by transecting a set or "stack" of axial images. Linear or curved oblique MPR provides useful sectioning with respect to specific maxillofacial anatomy such as the TMJ or dental arch. Subsequent serial trans-axial cross-sectional imaging provides sequential multiple thin-slice images, at right angles to the MPR.

2) Increasing Slice Thickness: The addition of the grayscale values of adjacent voxels of orthogonal or MPR sections are known as "ray sum" [6] and enables the production of simulated, but undistorted, projection images such as lateral cephalometric and panoramic images.

3) 3D Volume Rendering: These techniques allow the visualization of 3D data by selective display of voxels. This can be achieved by direct volume rendering (DVR) providing a volumetric surface reconstruction with depth, or indirect volume rendering (IVR), most commonly as a maximum intensity projection (MIP). MIP is used to demonstrate high intensity structures by providing a "pseudo" 3D reconstruction [7].

Appropriate Use of CBCT Imaging: Generally accepted guidelines state that CBCT should be used as an adjunctive diagnostic tool to existing dental imaging techniques for specific clinical applications & not as a screening procedure for diagnosing oral pathologies or dental caries etc [8].

Specific Clinical Applications [9]: CBCT has been applied to adjunctive diagnosis in all areas of dentistry including:

1) Implant Sites **-** The most common use for CBCT imaging is for the assessment of potential implant sites by providing cross-sectional images of the alveolar bone and accurately depicting important anatomic features (the mandibular canal in the mandible or maxillary sinus in the maxilla).

2) Orthodontics **-** Large FOV imaging of facial asymmetry craniofacial syndromes and maxilla/mandibular disparities can be demonstrated using 2- or 3-D formats allowing precise measurements of the skull and facial bones. Small regions can also be imaged to determine the exact position of impacted11 and/or supernumerary teeth and their relationships to adjacent roots or other anatomical structures.

3) TMJ **-** CBCT facilitates the visualization of bone morphology, joint space and dynamic function as compared to conventional imaging, a critical key to providing appropriate treatment in patients with signs and symptoms of TMJ pathology.

The presence of metallic restorations in the mouth can create streaks and dark band effects which present horizontally on axial (left), coronal (lower right) and sagittal (upper right) orthogonal images.

4) Oral Pathology **-** CBCT demonstrates the location, size, shape, extent and full involvement of pathology of the jaws. Various dental conditions including additional teeth (supernumeraries), impacted canines (Figure 4) and third molars are clearly identified.

CONCLUSION

Use of CBCT imaging by both general and specialist practitioner will undoubtedly increase. This technology provides the clinician with an imaging modality with increased precision, acceptable patient dose, and the capability of visualizing the third dimension. CBCT also extends dental imaging from diagnosis to image guidance for operative and surgical procedures. Practitioners using CBCT should be aware that guidance documents by relevant organizations will be periodically updated to ensure optimize image quality and minimize patient radiation exposure.

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CONFLICT OF INTEREST:
The authors declare that they have no conflict of interest.

STATEMENT OF HUMAN AND ANIMAL RIGHTS

All procedures performed in human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

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