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Review Article

Application of Cone Beam Computed Tomography in Dentistry- A Review

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ABSTRACT
Cone beam computed tomography (CBCT) is an absolutely recent imaging technology used to create 3-dimensional renditions of subjects. There are several uses of CBCT. Amongst all are- implant radiology, in endodontics, maxillofacial trauma, fracture assessment, root canal morphology, in forensic sciences, TMJ disorders etc. This article shows various applications of CBCT in dentistry.
Key words:- CBCT, Endodontics, TMJ disorders.

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INTRODUCTION

As in many fields of radiology, technological advances have led to the introduction of new methods also in dentomaxillofacial radiology (DMFR). One of these is cone beam CT (CBCT), which is also known as digital volumetric tomography (DVT). Dental CBCT technology first emerged in 1995 when Italian inventors Attilio Tacconi and Piero Mozzo introduced the first maxillofacial imaging device, the NewTom DVT 9000.[1] This scanner was introduced commercially in Europe in 1999. At the same time, Arai et al. also introduced their CBCT developments.[2]

Cone beam computed tomography (CBCT) is an absolutely recent imaging technology used to create 3-dimensional renditions of subjects. Following the commercial introduction of CBCT, unprecedented abilities to maxillofacial imaging emerged, immensely expanding the role of imaging within diagnostics and treatment. The benefits of good image quality, volumetric analysis, short scan times, and relatively less radiation dose than conventional medical CT, has resulted in greater ubiquity as an imaging modality within all disciplines of dentistry.[3]

COMPONENTS OF CBCT

There are many components of CBCT image production; the various factors, such as the scanning unit employed, examined object, FOV, contrast resolution, and spatial resolution defined by the voxel size may profoundly influence the image quality produced for interpretation. It is important to understand these details in order to pursue improvement in the modality on a clinical level.[4] Imaging from the CBCT is accomplished via a rotating gantry, from which a pyramidal x-ray beam is directed through the subject onto a contralateral sensor. The gantry will rotate around the subject simultaneously collecting multiple (from 150 to more than 600), sequential, full-volume, planar projection (2D) images within an assigned field of view (FOV), each individually known as basis images. These

basis images are used to mathematically reconstruct the 3-dimensional volume for viewing and manipulation.[5]
Dental CBCT utilizes a cone- or pyramid-shaped X-ray beam which is directed on the pursued maxillofacial field-of-view (FOV). Most of the modern CBCT scanners use flat panel detectors (FPD) comprising of a pixel array of amorphous silicon thin-film transistors (TFT) or complementary metal oxide semiconductors (CMOS). For both of these, X-rays are first converted to light photons by a scintillator material which may consist of thallium doped caesium iodide (CsI:Tl) or terbium activated gadolinium oxysulphide (Gd2O2S:Tb). Thereafter, the light is detected on the photodiodes and finally read from the entire detector array to compile a projection raw-data digital image. Flat panel detectors offer higher spatial resolution and greater dynamic range, and are less bulky and complicated compared to image intensifiers (II) and charge coupled devices (CCD) which have gradually become obsolete as CBCT detectors.[6]

FIELD OF VIEW (FOV)

The FOVs available in dental CBCT systems vary from FOVs suitable for a single jaw (D × H usually 4 × 4 cm2 or 5 × 5 cm^2) to full craniofacial imaging (from approximately 15 × 15 cm2 up to 23 × 26 cm^2). The dimensions of the FOV depend on the size and shape of the detector, the beam projection geometry and the ability to collimate the beam. The reduction of the FOV in most units is performed by using adjustable lead shields as a primary collimation at the radiation source. Moreover, most of the systems utilize either one or a few prefixed FOVs planned for different indications, whereas in some devices one can freely adjust the FOV within certain limits in both the vertical and the horizontal cross-sectional volumes.[7]

APPLICATION OF CBCT

There are numerous uses of CBCT. It can be useful in TMJ disorders, in endodontics, in implant surgery etc.

FRACTURES

CBCT the technique of choice for investigating and managing midfacial and orbital fractures, postfracture assessment, interoperative visualization of the maxillofacial bones, and intraoperative navigation during procedures involving gunshot wounds. By utilizing advanced software, CBCT allows for minimum visualization of soft tissue, allowing dentists to control post treatment esthetics and evaluate the outline of the lip and bony regions of the palate in cases of cleft palate.[8] CBCT is used widely for planning orthognathic and facial orthomorphic surgeries, where detailed visualization of the interocclusal relationship and representation of the dental surfaces to augment the 3D virtual skull model is vital. [9]

TEMPOROMANDIBULAR JOINT DISORDER

CBCT helps in defining the true position of the condyle in the fossa, which often reveals possible dislocation of the disk in the joint, and the extent of translation of the condyle in the fossa. CBCT is the imaging device of choice in cases of trauma, pain, dysfunction, fibro-osseous ankylosis and in detecting condylar cortical erosion and cysts. Because of the use of the 3-D features, the image guided puncture technique, which is a treatment modality for TMJ disk adhesion, can safely be performed. With its accuracy, measurements of the roof of the glenoid fossa can be done easily. Soft tissues around the TMJ can also be visualized.[10]

IMPLANT DENTISTRY

CBCT is the preferred option for implant dentistry, providing greater accuracy in measuring compared to 2D imaging, while utilizing lower doses of radiation. New software has reduced the possibility of malpositioned fixtures and damaged anatomical structures.[11]

ORTHODONTICS

CBCT is a reliable tool in the assessment of the proximity to vital structures that may interfere with orthodontic treatment. Orthodontists can use CBCT images in orthodontic assessment and cephalometric analysis. Today, CBCT is already the tool of choice in the assessment of facial growth, age, airway function and disturbances in tooth eruption.[12]

ENDODONTICS

CBCT has been proved beneficial in assessing the exact anatomy and morphology of root canals. Increased number of MB2 canal can be identified with CBCT when compared to conventional radiographs.
Conventional radiography results in an under-estimation of the incidence of apical periodontitis. Lesion confined within the cancellous bone cannot be detected by conventional radiographs, whereas they are easily detected in CBCT which captures images in slices thereby avoiding anatomic superimposition. Thus, apical Periodontitis can be detected at an early stage using CBCT when compared to conventional radiographs.[13]

PERIODONTICS

The first reported applications of CBCT in Periodontology were for diagnostic and treatment outcome evaluations of periodontitis. It has ability to accurately reconstruct periodontal intrabony and fenestration defects, dehiscences, and root furcation.[14]

ARTEFACTS

Noise

Although noise is commonly not dealt with as an artefact, it is an image deteriorating factor.20 Two sorts of noise have to be considered in the reconstructed images: additive noise stemming from round-off errors or electrical noise, and photon-count noise (quantum noise) that should be expected to follow a Poisson distribution. Other authors also include detector blurring in the term ‘‘noise.’’ CBCT machines for dose reduction reasons are operated at milliamperes that are approximately one order of magnitude below those of medical CT machines.[15]

Scatter

Scatter seems to also be a very important artifact causing factor in CBCT. The basic concept behind the radiographic imaging process as described in Equation 1 is that only photons travelling directly (i.e. in a linepath) from the source to the detector are measured. Scatter, on the other hand, is caused by those photons that are diffracted from their original path after interaction
with matter.[16]

Extinction artefacts

These are often termed ‘‘missing value artefacts’’. If the object under study contains highly absorbing material, e.g. prosthetic gold restorations, then the signal IP recorded in the detector pixels behind that material may be close to zero or actually zero.[17]

Beam hardening artefacts

Beam hardening is one of the most prominent sources of artefacts. The lower energetic (lower wavelength) rays of the polychromatic spectrum emitted by the X-ray source may suffer substantial absorption when passing through the object under study. The more dense the latter and the higher the atomic number it is composed of, the larger the share of absorbed wavelengths. Highly absorbing material such as metal functions as a filter positioned within the object.[18]

Although CBCT has a relatively lower radiation dose to patients than medical CT, practitioners must be prudent in prescribing imaging in adherence to the ALARA principle (radiation dose ‘as low as reasonably achievable’).[19] A myriad of factors contribute to the radiation exposure, among which are the aforementioned user adjustable settings of voxel size and FOV. Other factors include scan duration, milliamperage, kilovolt potential, filtering, patient positioning, and the sensor technology and proprietary algorithms used in the device itself.[20] All of this makes CBCT dosimetry inherently difficult to summarize. To further obfuscate, much of the research available relies on different methodologies and comparisons to draw conclusions about radiation exposure.

Conclusion

The dental profession now has the ability to generate full 3D images of our patients’ dental and maxillofacial complex. These images are reliably accurate with no magnification and unfettered by superimposition from other anatomic structures.

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