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RESEARCH ARTICLE

Cone-beam computed tomography-A boon to dentistry.

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Abstract

Imaging is the most important and frequently used diagnostictool in dentistry.Although the history and clinical examination areof prime importance when evaluating patients, the use andevolution of non-invasive technology from two-dimensional(2D) X-ray modalities to three-dimensional (3D) cone beamcomputed tomography (CBCT), for imaging is increasinglybecoming popular.Interest in CBCT fromall fields of dentistry is unprecedented because it has created a revolution inmaxillofacial imaging, facilitating the transition of dental diagnosis from 2Dto 3D images and expanding the role of imaging from diagnosis to imageguidance of operative and surgical procedures by way of third-party applicationssoftware.

Introduction:-

Since introduction in the late 1990s, cone beam CT (CBCT) has become a common modality to image the facial skeleton. CBCT has been described as the 3D method of choice for maxillofacial imaging due to the lower cost of the equipment and test, the reduction in radiationlevel in comparison with multi-slice computed tomography, high resolution for bones and teeth,and the possibility of obtaining the whole set of traditional orthodontic images in only one exposure.[1]

The American Association of Oral and Maxillofacial Radiology has stated that cross-sectional views are recommended for planning dental implants, and this in combination with the easy accessibility, easy handling, and low-radiation dose of CBCT imaging will lead to the widespread use of CBCT imaging in implantology.[2]Oral implants require localized area of oral and maxillofacial area for radiation exposure; so, CBCT is an ideal choice. CBCT scans help in the planning of oral implants; they enable measurement of the distance between the alveolar crest and mandibular canal to avoid impingement of inferior alveolar nerve, avoid perforation of the mandibular posterior lingual undercut, and assess the density and quality of bone, and help in planning of the oral implant in the maxilla with special attention to the nasopalatine canal and maxillary sinus.[3]If CBCT was equal to a full-mouth series in efficacy,it could be argued that, depending on machine type, the radiation risk would be considerably less, as would the time and effort it takes to image the patient.

Background:-

The Imaging of CBCT is achieved by operating a rotatory gantry to which an imaging x-ray tube and image receptor are fixed. A deviating pyramidal-or cone-shaped source of ionizing radiation is focussed through the center of the

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area of interest onto an area image receptor on the opposing side. The x-ray tube and image receptor rotate around a rotation fulcrum fixedwithin the center of the region of interest. During the rotation, multiple (150 - 600) sequential planar projection images of the fieldof view (FOV) are obtained in a complete or partial arc. This technique varies from a traditional medical CT machine, which uses a fan-shapedx-ray beam in a helical progression to acquire individual image slices ofthe FOV and then heaps the slices to acquire a 3D image. Each slicerequires a distinct scan and separate 2D reconstruction. Since CBCTexposure incorporates the entire FOV, only one rotational sequence of thegantry is necessary to acquire enough data for image reconstruction.[4]

The four components of CBCT image production are (1) acquisition configuration, (2) image detection, (3) image reconstruction, and (4) image display.The dimensions of the FOV or scan volume able to be covered depend primarily on the detector size and shape, the beam projection geometry and the ability to collimate the beam.During the scan, single exposures are made at certain degree intervals, providing individual 2D projection images.The resolution, and therefore detail, of CBCT imaging is determined by the individual volume elements or voxels produced from the volumetric data set. In CBCT imaging, voxel dimensions primarily depend on the pixel size on the area detector, unlike those in conventional CT, which depend on slice thickness.[4]

Benefits of cone-beam CT in dentistry:-

CBCT equipment occupies less room space compared to conventional CT machine. Structural relationships of hard and soft tissues canbe observed directly. The ability to rotate images and toadd or subtract structural components permitsrelationships to be studied. Contiguous structures canbe separated and normal hidden surfaces examined indetail. Accurate linear and volumetric measurementscan be made. It eliminates superimposition of images ofstructures outside the area of interest.CBCT imaging produces images with sub millimetre isotropic voxel resolution, which achieve accurate level of spatial resolution for maxillofacial imaging. Images of the patient can be acquired in sitting, standing or supine position.CBCT volumetric data is isotropic, which means all three dimensions of the image voxels are the same. This makes it possible to reorient the images to fit the patient’s anatomic features and perform real-time measurements.[5,6]

Applications of CBCT in dentistry:-

Implant Dentistry:-

Conventional panoramicradiography is unable to imageadequate bony support preoperatively. Obviously,having this information preoperatively greatly reducesthe likelihood of the need to change thetreatment approach intraoperatively.The reported indications for CBCT use in implant dentistry vary from preoperative analysis regarding specific anatomic considerations, site development using grafts, and computer-assisted treatment planning to postoperative evaluation focusing on complications due to damage of neurovascular structures. It will be difficult to prove a clear and statistically significant benefit of cross-sectional imaging (with special emphasis on CBCT) over conventional twodimensional imaging such as panoramic radiography with respect to damage of the IAN or other vital neurovascular structures in the arches resulting in dysesthesia or pain in comparative prospective studies due to the high number of cases needed for such an evaluation .[7]

Orthognathic Surgery:-

A 3-dimensional modelcan be reliably adopted for orthodontic and orthognathicanalysis and surgical prediction, extensive researchis needed to characterize the landmarks andrelationships that this technology allows us to measure.As useful as cephalometric analysis can be, its imagingaccuracy is inadequate in such deformities ashemifacial microsomia, severe facial asymmetries, andocclusal cant. Volumetric analysis promises to offer better prediction in terms of the morphology of the defect, as well as the volume of graft material necessary for repair. Questions abound regarding the stability of the arch after grafting, the quality of the bone graft over time, and the effect on overall facial growth; CBCT provides a means to investigate these issues in depth. Onlydifficulty is how best to apply and manipulatethat data for more accurate surgery and treatmentplanning.[8]

In 2009, Swennen et al. recommended the following three-stage sequence for imaging when evaluating surgical treatment outcomes using CBCT: In Stage 1 (3–6 weeks post-operatively): imaging is used to verify the transfer of bony parts. This time frame circumvents post-operative soft tissue swelling which might interfere in occlusion and is prior to bony consolidation, thereby providing proper visualization of osteotomy lines.In Stage 2 (6 months to 1 year post-operatively: imaging at this stage evaluates the soft tissue response and should preferably occur after the removal of orthodontic brackets. In Stage 3 (2 years or more post-operatively): this imaging is used to evaluate long-term changes in surgical treatment.[9]

Orthodontics:-

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.[10,11]

While 3D CBCT images are most often used to assess skeletal contributions to malocclusion, researchers are now investigating the use of these images to assess dental relationships in orthodontic patients.[12]CBCT likely will provide information that could result in one or more of the following outcomes: (1) enhanced diagnosis, such as precisely localizing impacted and supernumerary teeth; (2) quantifying the magnitude of a defect or deformity, such as in patients with craniofacial anomalies; (3) improving differential diagnosis of skeletal, dental or combined malocclusions, including identifying the jaw(s) contributing to malocclusion and determining whether the discrepancy is bilateral or unilateral, such as in orthognathic surgery, asymmetry, craniofacial anomaly and open bite cases; and (4) helping to identify possible causes of malocclusions, such as the contribution of TMJ abnormalities to an open bite or asymmetry.[13]

The decision regarding the use of CBCT depends on the severity of malocclusion. The more severe the malocclusion, the more probability of needing the examination and similarly the milder the malocclusion, the less likelihood of needing a CBCT scans. Malocclusion severity is understood as the presence of vertical and sagittal skeletal discrepancies, facial asymmetry, craniofacial malformation and tooth eruptive disorders. There is no rationale in indicating CBCT for patients with Class I malocclusion and anterior crowding.[14,15]

Airway morphology and obstructive sleep apnoea:-

Cone beam computed tomography can better assess the cross-sectional dimensions of the airway space than conventional 2D radiography. The drawing of airway circumferences and calculation of cross-sectional areas by computer also greatly reduces operator-dependent bias.[16]Aboudara et al found much larger interindividual variations of the volume and area of the upper airway in cephalograms than with CT.[17]

Caries diagnosis:-

CBCT imaging appears to be the bestprospect for improving the detection and depth assessment of caries in approximaland occlusal lesions. Recent work with benchtop-based local orlimited CBCT (LCT) systems has demonstrated the potential for caries detectionand depth characterization by high-resolution systems.Further studies are needed to evaluate CBCT for the detection of occlusal or pit and fissure caries, a task for which 2D imaging has been weak.[18,19]

Periodontal applications:-

Mol et al observed that the CBCT images provided more accurate information on periodontal bone levels in three dimensions than the images of photostimulated phosphor plates. In a similar study, it was found that CBCT was better in morphological description of periodontal bone defects, while the images obtained by charged coupled device sensor provided more bone details.[20] Noujeim et al concluded that CBCT technique has better diagnostic accuracy than periapical films in the detection
of interradicular periodontal bone defects.[21]

CBCT measurements were foundto be equivalent to direct measurements and dehiscenceswere diagnosed with higher accuracy than fenestrations. CBCT images wereused for alveolar bone width measurements.Intrasurgical furcation involvement measurements were compared by using CBCT images and it was reported that CBCT images demonstrated a high accuracy in assessing the loss of periodontal tissue and classifying the degree of furcation involvement in maxillary molars.[22]

Endodontic applications:-

CBCT for endodontic purposes appears to be the most promising use ofCBCT, in many instances instead of 2D images. Endodontic applications include the diagnosis of periapical lesions due to pulpal inflammation, visualization of canals ,elucidation of internal and external resorption, and detection of root fractures. CBCT wasfound to be useful in differentiating solid from fluid-filled lesions (periapicalgranulomas from cysts) using grayscale values in the lesions.[23]

For most endodontic applications,limited FOV CBCT is preferred to medium or large FOV CBCT because there is less radiation dose to the patient,higher spatial resolution and shorter volumes to be interpreted.Limited FOV CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology,such as mandibular anterior teeth, and maxillary and mandibular premolars and molars, and dental anomalies.If a preoperative CBCT has not been taken, limited FOV CBCT should be considered as the imaging modality of choice for intra-appointment identification and localization of calcified canals.Limited FOV CBCT should be considered the imaging modality of choice if clinical examination and 2-D intraoral radiography are inconclusive in the detection of vertical root fracture.Limited FOV CBCT should be the imaging modality of choice when evaluating the nonhealing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical or extraction and for nonsurgical retreatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.[24]

Temporomandibular joint diagnostics:-

CBCT in general has an acceptable accuracy for diagnosing osseous TMJ abnormalities with fairly high sensitivity, although small abnormalities might be missed.CBCT most accurately depicted erosive changes of the bone cortex of the mandibular condyle.[25] The high detectability of CBCT images on bone morphology of mandibular condyles was observed.CBCT has also been found useful as an image-guided technique for safe puncturing of the superior TMJ space. CBCT has been applied in the evaluation of bifid mandibular condyles, coronoid hyperplasia and articular eminence morphology and to assess condylar remodelling accompanying splint therapy.[26] CBCT was applied in a series of cases of osteochondroma of the mandibular condyle and the value of 3D reconstructions when viewing expansive lesions was emphasized. CBCT has also been applied to cases with facial asymmetry and condylar hyperplasia,synovial chondromatosis, fibrous ankylosis in rheumatoid arthritis,metastasis of a bronchial carcinoma and juvenile idiopathic arthritis. [26, 27, 28]

Oral and Maxillofacial Pathology:-

CBCT is useful in evaluating the intricate anatomy of many unusual presentations, measuring their exact dimensions and their association with surrounding structures. CBCT scan is the imaging method of choice in pre and postoperative diagnosis assessment of inflammatory odontogenic cysts together with alloplastic graft materials repairement of the osseous defects and dental rehabilitation by metallic implants, due to high specific abilities in bone tissue 3D evaluation.Threedimensional imaging of cysts and tumors of the maxillofacial region can give the surgeon the vital information necessary for planning surgery; with volumetric analysis, this can help anticipate the need for and volume of a potential graft for reconstruction.[8,29] Various effects of cysts and tumours on the anatomic structures can be studied using CBCT.[30]

Oral and maxillofacial surgery:-

CBCT is the technique of choice in mid-face fracturecases, orbital fracture assessment and management and for inter-operative visualisationof the facial bones after fracture. Since itis not a magnetic resonance technique, it is thebest option for intra-operative navigation duringprocedures, including gun-shot wounds.CT is the modality of choice for the evaluation of complex facial fractures, especially those involving the frontal sinus, nasoethmoidal region, and the orbits.CBCT acquires all projection images in a single rotation, therefore scan time is reduced enormously (20 seconds or less), often performed with the patient in a seated position. Because the data are acquired volumetrically, voxel size is isotropic, equal in all 3 dimensions of the voxel, whereas conventional CT voxels are anisotropic, where the height of the voxel (Z-axis) is determined by slice pitch, a function of gantry motion.[31]

Prosthodontics:-

Other than implant planning, CBCT has its role in prosthodontics as 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.The 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 over dentures.[32]

Forensic dentistry:-

CBCT technology offers 3D visualization and more complex and more accurate imaging compared to analog and digital radiographs. Increasing availability of this technology provides the forensic odontologist with an imaging modality capable of providing a 3D representation of the teeth and the jaws whose benefits may be extended in several ways to the science of forensic odontology.Rai et al investigated age estimation based on the pulp-to-tooth area ratio (PTR) of maxillary canines measured in three planes (axial, sagittal, and coronal) obtained from CBCT image data.[33]

Limitations of CBCT:-

The spatial resolution and the contrast resolution ofCBCT is lower than that of conventional film-based or digital intraoral radiography . Radiographic artifacts are anotherproblem in CBCT imaging. The two types of artifact that can reducethe diagnostic yield of the images are distortion of metallicstructures, called “cupping artifact” and the appearance ofstreaks and dark bands between two dense structures , sothat these artifacts may reduce the diagnostic yield of images.The patient have to stay absolutely stillas his/her movement can adversely affect the sharpness ofthe final image during the scan.[34]

Effective dose of CBCT:-

Heterogeneity in measurementmethods and scanning protocols between studies madecomparisons of effective doses of different CBCT unitsand scanning protocols difficult. Few studies relateddoses to image quality. Reported effective dose variedacross studies, ranging between 9.7 and 197.0 mSv forfield of views (FOVs) with height #5cm, between 3.9and 674.0 mSv for FOVs of heights 5.1–10.0 cm andbetween 8.8 and 1073.0 mSv for FOVs .10 cm.[35]

Conclusion:-

In summary, with the continued decreasing cost ofCBCT technology, it is only a matter of time untilCBCT finds its way into the average dental practice. It is clear that the utility of the CBCT cannot be disputed. CBCT is capableof providing accurate, submillimeter-resolution images in formats allowing3D visualization of the complexity of the maxillofacial region.

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