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CONE BEAM COMPUTED TOMOGRAPHY: A BOON IN DENTISTRY

Dental Science

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KEYWORDS

INTRODUCTION

Cone beam computed tomography is a three dimensional radiograph used in dental diagnosis and treatment planning.CBCT shows the head and neck structures without overlap which enables the radiologist to identify the landmarks clearly.It all started with the discovery of x-rays by Wilhelm Roentgen in the late 1800s. CBCT has revolutionized the imaging of the maxillofacial region due to its wide range of applications across the fields of dentistry, ranging from diagnosis to treatment planning. CBCT exposure should be clinically justified for each patient based on the principle of keeping radiation dose "as low as reasonably achievable (ALARA)," which is supported by the American Dental Association.[1]

Applications of CBCT in dentistry

Endodontics

CBCT has been reported to be better than two dimensional radiographs in the diagnosis of periapical lesions.[2] It allows the visualization of lesions close to maxillary sinus as well involvement of membrane of maxillary sinus and proximity to mandibular canal.

Recently,however, CBCT has proven to be a promising diagnostic aid for complex endodontic cases, including the detection and visualization of extra canals, lateral canals, perforations, obturations, canal shape, and vertical root fractures. Conventional CT may detect around 70% of root fractures, but the higher cost and larger amount of radiation exposure limit the use of this technology by oral radiologists.CBCT can be helpful in establishing working length of the root canal while performing endodontic procedures. In addition, CBCT has helped in increasing the success rates of endodontic treatment as it helps in identification of accessory root canals.[3]

Periodontics

CBCT is a more reliable and reproducible method of assessing incipient furcation involvement, buccal and lingual periodontal bone defects, and the extent of intrabony defects than 2D radiography.[4,5] CBCT enables an accurate assessment of the outcome of regenerative periodontal therapy and bone grafts. CBCT has significant diagnostic applications in periodontics, conventional radiography can better depict bone quality, periodontal ligament space, and bone levels; accordingly, the decision to use CBCT imaging should only be made after careful consideration of its potential risks and benefits.

Implantology

Today CBCT is the most popular choice for the evaluation of implant insertion site.

CBCT provides cross-sectional images in several planes that help with the accurate assessment of the height, width, and angulation of bone, as well as with visualization of the position of the inferior alveolar canal and mental foramen in the mandible and the sinus in the maxilla.[6] In many situations, CBCT implantology has minimized or eliminated the need for procedures like bone and tissue grafts, as it enables precise measurement of the distance, area, and volume of the bone in which the implant is to be placed.[1,7] However, the American Academy of Radiologists (AAOR) has recommended panoramic radiography as the primary imaging modality for the initial assessment of the implant site. Cross-sectional CBCT images should be considered only when clinical conditions require sinus augmentation procedures or bone grafting, or if the patient reports implant mobility post-surgery.

Oral surgery

In the even of injury to oral and maxillofacial structures, CBCT can provide precise assessment of the surface continuity and distances between the different surfaces. In case of orbital fractures, midfacial fractures, mandibular fractures, and dentoalveolar fractures CBCT can provide valuable information for comprehensive evaluation of the fractures. CBCT allows the location of pathologies such as odontogenic tumors, cysts, osteomyelitis, calcifications. CBCT allows the inspection of unerupted teeth, impacted teeth, supernumerary teeth. Instead, 3D CBCT is a cost- and dose-effective alternative to conventional 2D imaging for the diagnosis of complex maxillary fractures.[8] It provides the surgeon with 3D-reconstructed images for analysis of the nature of the injury, the location of the fracture, and the degree of displacement of the fractured segments. Mandibular fractures are easily visualized on a panoramic radiograph in most cases; however, some cases require further confirmation by CBCT, including dislocation of fracture fragments in the mandibular corpus and split fractures in which the fracture line is not parallel to the X-ray beam[9]

Temporomandibular joint disorders

CBCT provides accurate evaluation of three dimensional images of Temporomandibular Joint (TMJ). It allows the evaluation of condyle, glenoid fossa, and surrounding structures.[10] CBCT can be viewed with multiplanar reconstruction images in axial images, sagittal images, and coronal images. It also allows the location of the mandibular condyle within the glenoid fossa. This can be helpful in identifying the potential problems with disc and dislocations of joint. CBCT is useful for assessment of developmental anomalies of condyle, trauma of mandible and TMJ, ankylosis, cortical erosion and osteoarthritic changes in the condyle. CBCT has been found to be most useful in the evaluation of bony changes of the TMJ, such as fractures, ankylosis, dislocation, growth abnormalities, and various degenerative joint diseases including osteophytes, erosions, flattening, subchondral sclerosis, and pseudocysts.[11]

Orthodontics

CBCT allows the orthodontist to evaluate the hard and soft tissues of face in lateral cephalometric view as well as frontal posteroanterior view as well as panoramic view.[3,13] CBCT can also be used to evaluate the thickness and density of palatal bone, ramal bone, buccal bone for the application of mini implants in orthodontics In recent years, aligners have gained wide popularity in the orthodontic field. This is because of their esthetic appearance as compared to fixed orthodontic appliances. With the advanced understanding of aligners, even complex tooth movements can now be undertaken with aligner therapy. The effects of orthodontic intervention such as rapid palatal expansion and mini implant supported rapid palatal expansion can be investigated with the help of CBCT . CBCT has been introduced as a technique for comprehensive orthodontic imaging and for the assessment of tooth movement in all 3 planes.[14]

Artificial intelligence

The assessment and interpretation of CBCT images are complex, time consuming, and operator sensitive. Different machine learning techniques have been researched for this purpose. One particular method for evaluation of CBCT is a feature based and voxel based method for automated landmark identification in a CBCT. Recently, deep learning based methods have been applied to evaluate CBCT scans.[15] This method has shown some promise but further research is required for the assessment of the automated landmark identification and segmentation in CBCT scans.

Forensic odontology

Estimation of the ages of living or deceased individuals is an important aspect of forensic investigation. Several techniques to estimate the age of individuals by analyzing teeth have been reported in the literature.[16] Various methods have been developed to study the size of the pulp chamber, including tooth cross-sections and radiographs; however, CBCT provides a 3D view of the pulpal cavity, facilitating a more accurate estimation of the dental age of an individual.[17] CBCT also provides accurate and reliable measurements of soft tissue thickness for specific landmarks of the face and scalp by producing facial reconstruction at reduced exposure and increased speed, and it provides higher-quality images than spiral CT and other methods.[18]

CBCT is currently used in forensic investigations for postmortem imaging and for imaging high-density metal projectiles in cases of gunshot injury.

Future perspectives

Optimization of CBCT images

Compared with other modalities, CBCT has been documented to have high diagnostic efficacy in the accurate detection of complex oral and maxillofacial pathologies. This efficacy could be increased further by the optimization of CBCT with respect to various parameters, such as reduction in focal spot size, alteration of beam geometry, an increase in detector efficiency, and optimization of exposure and image reconstruction.[19]

Optical scanners with CBCT

Recently, the diagnostic process has been enhanced by the introduction of optical scanners, and combination of these techniques with CBCT could lead to improved treatment planning. Although CBCT can provide cross-sectional 3D images of the maxilla and the mandible for implant surgery, it cannot replicate the surface details and occlusal morphology of teeth.

Non-odontogenic pathologies

While CBCT scans were initially used exclusively for imaging the dentomaxillofacial complex, the use of this technique has expanded to include the visualization of non-tooth-related pathologies and abnormalities in the head and neck region, mainly sinus pathologies, such as mucosal thickening, partial opacification with liquid accumulation, total opacification, and polypoidal mucosal thickening. CBCT images provide complete diagnostic information regarding sinus pathologies with higher spatial resolution than multidetector computed tomography.[20] Tumors of the skull base are better visualized with MRI than with CBCT, but CBCT does play a crucial role in the detection of calcification processes, as well as in situations requiring sinus lifting or bone augmentation procedures.

Phase contrast tomography

The literature includes numerous studies investigating the X-ray absorption of the object under study in phase contrast tomography, but the phase nature of the X-rays still requires further exploration. Recently, researchers have introduced quantitative phase-contrast cone-beam tomography, in which the phase coefficient rather than the attenuation coefficient is used to reconstruct the image.[21] This technique utilizes unfiltered radiation from a small polychromatic source, thus reducing high spatial frequency noise and contributing to high soft tissue contrast.

CONCLUSSION

This review article discussed the basics of CBCT and the uses of CBCT in different dental fields. CBCT allows the evaluation of various oral and maxillofacial problems. Until recently two dimensional imaging has been used in dentistry for diagnosis and dental treatment.[22] Now with the advances in CBCT, it has become the new standard for dental imaging for many conditions. CBCT provides lower radiation than computed tomography and has a shorter scanning time than computed tomography. CBCT has been used extensively in the field of oral and maxillofacial surgery for diagnosis of preoperative, intraoperative and postoperative evolution.[23] In orthodontics, CBCT plays a vital role in diagnosis, evaluation of facial growth as well as discrepancies in dental eruption. Furthermore, CBCT is useful in treatment planning especially for surgical cases, generation of computer designed splint.[24]

Future efforts to improve this technique should most likely be directed towards reducing the scan time; providing multimodal imaging (conventional panoramic and cephalometric, in addition to CBCT imaging); improving image fidelity, including soft tissue contrast; and incorporating task-specific protocols to minimize patient dose (for example, high-resolution, small FOV, or medium-resolution imaging for dentoalveolar imaging, or large FOV for dentofacial orthopedic imaging).[25] The combination of CBCT with optical imaging and phase contrast tomography, as well as the extension of its application for non-dental pathologies would be revolutionary steps in the coming decades.[26] CBCT provides a lot of information and therefore, the assessment and interpretation of CBCT images are complex, time consuming, and operator sensitive. Therefore, automated identification of CBCT landmarks with machine learning or artificial intelligence can make CBCT evaluation more efficient for the clinicians.

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