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Latest developments in cone beam computed tomography

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Abstract
Cone beam computed tomography (CBCT) has undergone considerably developments in the past few years. The objective of this review is to present the latest developments in CBCT in dentistry by forming a summary of the basic characteristics of CBCT and its applications in different aspects of dentistry. The review focuses on developments in terms of CBCT reconstruction and quality. CBCT examination can be performed in different dental fields. The filed of view for acquiring a CBCT can change according to the purpose of recording the CBCT. The use of CBCT in dental fields are presented in this review. Future directions with CBCT and new developments in radiographic imaging interpretation such as artificial intelligence are also described in this review article.

Keywords: cone-beam computed tomography, cbct, three dimensional radiographs, dentistry

Introduction

Cone Beam Computed Tomography (CBCT) is a latest development which is very helpful in oral and maxillofacial radiology because of the ability to records and measure volumetric aspects of the data [1, 2] CBCT was introduced in Europe and USA at the beginning of 21st century [3]. It has developed to be a valuable asset for the diagnostic and treatment planning aspects of dental treatment [4]. Dental specialist record CBCTs more often than the clinical general dental practitioners. This has been due to the increased emphasis on CBCT in the predoctoral curriculum at various schools. This review will discuss in detail about the new paradigms in diagnosis with the development of CBCT.

Materials and Methods

Technical aspects for using a CBCT

The CBCT appliance contains a pulsating x-ray generator with a cone shaped x-ray-beam which is focused on the object and passes through the object to the x-ray-beam detector. The detector receives the beam which is attenuated through the passage of x-rays through the tissues [5]. The imaging apparatus can revolve around the patient in either 360 degrees turn, or 180 degrees turn. The patients are required to stay still without movement during the rotation of the imaging apparatus around the patient. This is to prevent any motion artifacts on the x-rays. The position of the patient can be either standing, sitting, or supine. The sitting may have a benefit of reducing patient movement and increase comfort compared to standing [6]. The x-ray data acquired by the detector undergoes processing with the algorithms used to reconstruct the volumetric three dimensional (3D) radiograph.

Characteristics of CBCT

Spatial resolution of CBCT determines the sharpness of a CBCT scan [8]. This property defines the ability to capture the minute details of a CBCT scan such as the minimum distance to make a distinction between two closely placed objects [8, 9]. Like in a two dimensional (2D) radiograph, pixel is the unit of image, voxel is the unit of 3D radiograph [10]. The voxel size affects the spatial resolution of a CBCT image. The field of view also influences the spatial resolution. A small field of view CBCT frequently has a high spatial resolution and can be expected to show higher definition of structures and differentiation between closely placed structures more effectively than a higher field of view [11, 12]. Contrast resolution is the ability to distinguish the structures with variable densities [13]. Typically, CBCTs can provide good contrast resolution for hard-tissue structures such as teeth and bone. The low contrast of CBCT can cause difficulties in identification of soft tissue structures [11].

Developments in CBCT volumetric reconstruction and quality

The raw data is composed of 2D projections frames in CBCT. It undergoes several steps for the processing such as offset, and gain-corrections and is processed to lead to reconstructed volumetric data. A common process used for reconstruction is the filtered-back-projection with Feldkamp-Davis-Kress algorithm [13]. Image quality of CBCT is dependent on the noise and other artefacts that occur during the recording process [14]. The artefacts from patient movement, image-apparatus related issues lead to with blurring of the CBCT scan or stripe patterns on the CBCT scan. The noise in the CBCT system can be decreased by using high quality sensors and signal-transmission system. Metal appliances also lead to artefacts in the CBCT image.

Discussion

Use of CBCT in dentistry

Naso-oro-pharyngeal Airway and paranasal sinuses: CBCT can be utilized to visualize the airway boundaries in three dimensions and calculate the volume of the airway structures [15]. It can be used to assess the structures such as frontal, maxillary, ethmoid sinus, superior, middle, and inferior meatus, Pharyngeal tonsils, Rosenmuller dimple, palatine tonsils, Glosso-epiglottic furrow. The volumetric measurement of airway is a welcome addition to the linear measurements performed in two dimensional radiographs as it gives better information about the dimensional capacity of the airway [16]. With CBCT, the minimal cross-sectional area of airway for a patient can also be identified [17]. It has been noted that the minimal cross-sectional area of airway is less in patients with obstructive sleep apnea. Thus, it can be a good tool to screen for patients with airway issues. Furthermore, techniques such as palatal expansion technique with mini implants can be useful in improving the airway volume of patients [17]. Thus, CBCT is an important tool in the dentist's arsenal.

CBCT can also be used to evaluate the facial skeleton and the structures of head and neck [18]. Some of the important structures in the head and neck such as the piriform aperture, nasal bone, vomer, Maxillary bone, palatine bone, zygomatic bone, Mandible, mandibular foramen, mental foramen, Lacrimal bone, Inferior nasal concha, and Hyoid bone can be easily evaluated in three-dimensions with the help of CBCT. The discrepancy with maxilla and mandible can be in the anteroposterior dimensions leading to Class I, Class II, or Class III malocclusion. CBCT would allow the identification of such malocclusions and the contributing factors for the malocclusion whether dental, skeletal, or a combination of both and also the effects of treatment such as retraction of teeth [19].

Temporomandibular Joint (TMJ) evaluation can be performed with CBCT as it allows the visualization of the mandibular condyle, glenoid fossa of temporal bone, and the space between the two components of the TMJ [20]. Moreover, the articular tubercle and its length and orientation can be assessed with CBCT. CBCT allows the visualization of condyle and glenoid fossa in sagittal, coronal, and axial view. So the anterior pole, mesial pole, lateral pole, and posterior pole of condyle and glenoid fossa can be evaluated with a single CBCT without superimposition of structures [21]. The effects of dental appliances on TMJ have been investigated with CBCT [22]. It has been reported that expansion appliances can affect the position of condyle after the expansion. Recently, it has been shown that expansion appliances do not lead to long term changes in condylar position [23]. These evaluations have become possible due to the versatile applications of CBCT.

CBCT can be used for the assessment of the cervical vertebrae [24]. Atlas and axis are the first two cervical vertebrae. The evaluation of cervical vertebrae can be performed in different planes to observe the normal development and identify any abnormal pathologies. CBCT is not affected by the change in patient position and head orientation while recording the CBCT. AS the orientation of a CBCT can be modified in the imaging software used to visualize the reconstructed CBCT. This is an important advantage over the two dimensional radiographs as in 2D radiographs, the patient position and head orientation affects the measurement of the structures. It has been reported that the cervical vertebrae maturation seems to be higher when the head is rotated in roll and yaw [25].

CBCT play an important role in planning for dental implants [26]. CBCT can allow the evaluation of the bone height and bone width for implant placement. Moreover, the bone quality surrounding an implant can also be investigated based on CBCT evaluation post implant placement [27]. CBCT has also been used for placement of temporary mini-implants in orthodontics [28]. Mini-implants can be placed in buccal or palatal aspects and in maxilla or mandible. In maxillary palatal region, mini-implants can be inserted on one side of the mid-palatal suture or on both sides of the mid-palatal suture [29].

Future studies

CBCT is a 3D technology that has allowed three dimensional evaluation of the structures which was not possible until a few years back. Now with the help of CBCT, the radiographic files can be converted to stereolithography files (stl) and used for 3D printing [30]. Moreover, the use of artificial intelligence for the detection of the radiographs is a technology that has undergone rapid development in the past few years [31]. The use of artificial intelligence for identification of such three dimensional radiographs will be very useful to the clinicians in the future.

Conclusions

All the different aspects of dentistry can reap the benefits of the three dimensional radiographs such as CBCT. It could be used as a primary radiograph or a secondary radiograph to confirm he preliminary findings. The limitations of CBCT such as extra radiation, artefacts specially with metal objects must be taken into consideration while recording CBCT. In the future, the improvement in the CBCT technology and the development of artificial intelligence will lead to a reduction in radiation dosage and improvement in diagnostic ability.

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