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Literature Review Article

Cone beam computed tomography and applicability in Dentistry – literature review

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Abstract

Introduction: An appropriate treatment planing is essential for successful rehabilitation in Dentistry. The cone beam computed tomography (CBCT) represents a valuable resource in dental practice because it allows the establishment of a precise treatment plan by means of diagnostic imaging. **Objective:** To review the literature on CBCT. The history of development of this technique, its benefits and its applicability in different areas in Dentistry will be considered. **Literature review:** The CBCT offers advantages over the quality and quantity of anatomical data and promises less distortion of the image with low doses of radiation. It has been established as a valuable technique in the dental specialties. **Conclusion:** The use of CBCT as a diagnostic method must have precise and appropriate indication to provide adequate cost-benefit effectiveness in the patient's treatment.

Introduction

The adequate treatment planing is indispensable for the rehabilitative success in Dentistry. The evaluation of surrounding dental structures through imaging resources is one of the prerequisites and it has been used by several dental specialties.

The multiplanar ability of generating images in axial, coronal and sagittal planes are provided by computed tomography (CT), magnetic resonance, ultrasound and cone beam computed tomography (CBCT). These semiotics resources enable the professional to recreate the anatomical forms with simple functions increasing the efficacy in diagnosing the clinical cases [2, 12, 20].

Literature review and Discussion

CT development dates from the last of 1960s. However, it was patented by Hounsfield, and British engineer in the year of 1973. The invention promoted an immediate and profound impact in the imaging diagnosis granting him the Nobel Prize in Medicine, in 1979 [21]. From that moment on, the tridimensional imaging provides dramatic changes in medical and surgical practice. With the use of a new technology through the years, the professionals were able to apply this technology for the benefit of the patients [24]. The first generation of CT devices obtained data only in the axial plane of the patient, slice by slice, through a thin beam of x-rays penetrating a single matrix of detectors. In the last three decades, considerable advancements in technology allowed scanning in different planes; currently the scanners have a linear matrix of multiple detectors that obtain several cuts simultaneously, that are “piled up” and reformatted to obtain tridimensional images [21].

CBCT was initially developed for the use in angiography [24, 27]. It is a technique of tridimensional image acquisition developed in the last decades of the past century based on the application of the x-ray beams as conical-shaped centered in image detectors. At the ending, the morphology of the region is reconstructed in 3D by a data set converter by using a modification of the original cone beam algorithm developed by Feldkamp *et al.* in 1984 [30]. CBCT was previously used by radiotherapy and it has been applied in nuclear, war and spatial industry, in addition to medicine [6]. This technology was introduced in dentomaxillofacial imaging between the years of 1998 and 1999 [8]. A source of conical-shaped ionizing radiation is directed through the middle of the area of interest towards to an area of x-ray detection at the opposite side. The radiation source and the detector rotate around a fixed fulcrum inside the center of the area of interest. During the rotation, from 150 to 600 projections of planar sequential images of the field of vision are completely or partially acquired and, following, they are piled up to obtain a 3D representation. This procedure is different from traditional CT, because it uses a fan-shaped x-ray beam at a helical progression to acquire individual slices by image. CBCT comprises the entire field of view (FOV) and, at only one rotation sequence, it is able to acquire sufficient data for reconstruction [27]. The quality images and the resolution capability of CBCT are influenced by some variables including the device type, FOV, voxel size, current and tube voltage and other technical factors [15].

The first CVCT devices were commercially available in 2000 [20]. In USA, the devices started to be used in 2001 [14]. Since that moment, the researches show the use of this technology in Dentistry, so that the scanners have been constantly improved for use in dental offices [20].

CBCT systems commercially available are categorized according to the detector technology and design: a combination of devices coupled to an image intensifier tube or flat screen detector. This latter exhibits less influence of artifacts which are defined as distortions in images caused by metals, such as those within either restorations or orthodontic brackets [13].

There are four important 3D views: axial, transversal or sagittal, panoramic or coronal and the 3D reconstructions. The panoramic image reconstructed from the data set of CBCT differs substantially from that produced in the conventional panoramic radiograph and it can be viewed through software for the evaluation of the most comprehensive aspects of the arch [11]. CBCT enables the planing in virtual 3D softwares [6, 13]. The literature has shown that these softwares show the morphology with a clinically significant way and that the primary reconstruction of the data is completed parallely to the occlusal plane, which becomes the landmark. Other authors still affirmed that the reconstructions can also occur at the curve planes and oblique vision [14].

The position of the patient in the CBCT shot for the bucomaxillofacial region is either sitting or standing instead of only supine [6, 13, 27]. The device which demands that the patient lays at dorsal decubitus, occupies a larger area of surface or physical space and it cannot be used for physical impaired patients; also the units where the patient stays standing cannot be adjusted for an adequate height to fit a wheelchair; so devices where the patients stays sitting are more viable and comfortable. However, the head support devices more important than the patient orientation [27].

CBCT is already known as multi-slice tomography and it is a diagnosis record that currently promises less image distortion without superimposed structures [25]. The technological advancements in 3D images offer significant advantages regarding to the quality and quantity of the anatomical data because of the accuracy and proximity with the reality [16].

This technique decreases the “noise”, which can be interpreted as image variations from electronic, artifact or purely stochastic interferences, interposing in the quality and detection of important structures, fact very evident in 2D image [10].

CBCT uses a radiation dose significantly smaller than conventional CT [1, 4, 6, 8, 9, 11, 12, 14, 19, 21, 24, 30, 31]. This technique enables a reduction in the radiation absorbed by the patient because it utilizes a single 360° rotation and a cone beam, while spiral CT comprises several rotations and a fan beam [6, 13]. The radiation dose in CBCT is about 40% smaller than CT, but still 3 to 7 times greater than that of the panoramic radiographic examinations. This fact reinforces that when a 3D image is required, CBCT should be the method of choice [28].

The authors have emphasized the resolutive spatial superiority of CBCT in relation to CT [31]. The voxel size in CBCT can be up to 0.1 mm. This fact enables the establishment of a resolution greater than CT which reaches only to 0.5 mm [6, 13]. The disadvantage of CT is its high cost and the device size, generally inside hospital environments [6, 21].

CBCT introduction creates new diagnosis resources in Dentistry and it has been established as a valuable technique in bucomaxillofacial, oral surgery and orthodontics specialties [2, 4, 8, 15]. This technology becomes and indispensable diagnosis tool to be applied in different clinical applications, including: evaluation of the receptor site of osseointegrated implants and bone defects; bone graft procedures; evaluation of impacted teeth; orthodontic and endodontic planing; investigation of the TMJ disorders; procedures of sinus augmentations and orthognathic surgeries [11].

A comparative study revealed that the identification of cephalometric points used in the orthodontic planing was significantly more accurate with CBCT than with conventional lateral cephalogram [18]. The volume of the airways and respiratory function are highly relevant for this specialty, because different types of malocclusion and nasal obstruction are important etiologic factors for dentofacial anomalies. Obstructive sleep apnea exhibits craniofacial differences such as the size and position of the mandible, enlargement of the posterior air space and tongue and soft palate size. The use of CBCT to evaluate the airways can provide clinically useful information for the orthodontic treatment [12].

A study comparing the direct oronasal anthropometry with 3D through surface molds created from CBCT in cadavers showed the superiority of this latter technique. The data set obtained by CBCT was accurate and exhibited an excellent reproducibility compared with the manual method. Additionally, the second method was faster in collecting the data, less invasive and enabled the obtained of a 3D file of the facial morphology of the individual [9].

A study comparing the vertical angulation of all canines of 29 patients at the final phase of the orthodontic treatment concluded that the panoramic radiograph exhibited distortions in the images. This limits its value as a method for assessment of the tooth angulation and mesiodistal angles, which were always greater than those measured through CBCT [25].

The images of the cysts and tumors in the maxillofacial area can provide the bucomaxillofacial surgeon the information necessary for the surgery planing; with an accurate volumetric analysis, the CBCT scanning can predict the need and volume of a potential graft for reconstruction. Although the magnetic resonance examination is considered as the gold standard in the evaluation of the temporomandibular disorders, the condition of the bone components of the joint is offered with excellence by CBCT [24].

CBCT has been considered as an imaging modality very adequate for the assessment of the craniofacial area. It provides clear and accurate images of the structures, and therefore, it is extremely useful for the evaluation of the bone component. The transversal images can be used for obtaining more information on the appearance, location and path of the root canals and their relationship with other mandibular anatomical structures, including the tooth apexes [3].

Some authors considered CBCT as fundamental to evaluate the position and path of the inferior alveolar canal, mainly in cases of surgical intervention. This avoids nervous damages such as neuropraxia, axonotmesis and neurotmesis caused by either dilacerations, compression or stretching of the inferior alveolar nerve [7].

The literature suggests that CBCT is more sensible than conventional radiographs regarding to the location of included canines and root resorptions of the surrounding teeth. In 2D projections, a wrong interpretation can occur because of errors caused by projection distortions and blurred images [1]. It is clear the value of the CBCT in the planing of implants, surgical evaluation of the diseases, temporomandibular conditions and pre- and post-evaluations of the craniofacial structures [8, 11, 18].

Due to the increase of the requirement for rehabilitation of edentulous mandibles through osseointegrated implants the knowledge of the variations in dimensions and morphology of the endosseous arteries is very important. A study evaluating the distribution of endosseous canals in mandible through CBCT found these structures in 85% of the patients. This fact reinforces the indication of this technique in the pre-operative diagnosis, reducing the risk of surgical complications [26].

The literature describes the rich anatomical details provided and the importance of this resource in the surgical planing in Implantology. With the advent of CBCT, a valorization of important anatomical structures such as the maxillary sinuses, lingual and mental foramens, the level of bone resorption in edentulous areas and vascular and surrounding nervous bundles/branches [2]. An *in vivo* study revealed the success in the pre-operative orientation through CBCT in maxillary sinus augmentation and implants installation without transalveolar flap [8].

The traditional radiographs provide adequate information on the sites for installation of osseointegrated implants. However, the limited size of the film, the image distortion, the enlargement and the 2D view generates data and measurement inaccuracy. Thus these factors limit their use [6, 22]. Studies confirmed the existence of the enlargement rate in panoramic radiographs and suggested the CBCT utilization for the pre-operative evaluation in Implantology. CBCT eliminates this limitation and increases the examination accuracy [18, 31].

CBCT avoids the potential complications such as paresthesias, coming from the cortical bone perforation, reaching the inferior alveolar nerve, mental foramen and incisive canal; or seven the bad positioning of the implant inside the bone without the adequate surrounding bone volume, compromising its stability. The cross-sectional image is excellent for defining a cut in which the height and width of the bone can be accurately assessed. The simulated implants can be positioned into the ideal place for posterior rehabilitation [11].

In Endodontics, limited CBCT scanners capture small volumes that may include only two or three individual teeth. The images obtained eliminate the superimposition of the anatomical structures, such as the roots of the posterior teeth and their periapical tissues. These structures can be visualized separately at the three orthogonal planes without the superposition of the zygomatic bone, alveolar bone and surrounding structures. Additionally, the thickness of the cortical plate, the pattern of the bone marrow, presence of fenestrations, inclination and morphology of tooth roots, as well as the number of divergent and convergent canals can be detected. The presence of not identified canals, consequently not treated, it is easily identified at the axial cuts. They cannot be readily seen in the periapical radiographs, even those obtained at different angles [21].

The correct diagnosis of the anatomical variations is important for the success of the endodontic treatment. An *in vitro* study analyzing the morphology of the root canals in human teeth concluded that the tridimensional image provided by CBCT is a great advancement as an auxiliary method to establish the endodontic diagnosis [5]. A comparative *in vitro* study revealed that CBCT accuracy in detecting periapical lesions chemically induced was higher than that from conventional and digital radiographic images. This result is explained by the fact that in an image in layer, the difference between the lesion and its surrounding bone is greater resulting in a better contrast than that of 2D images [29]. Other *in vivo* study demonstrated that 25.9% of the periapical lesions in the pre-operative period of the apical surgery diagnosed in the CBCT examinations had not been detected by periapical radiographs. These findings once more reinforce the resolutive superiority of CBCT [4].

The authors emphasized that among the disadvantages of the panoramic radiograph are: projection of anatomic structures and differences in the mandibular morphology (like the mylohyoid nerve impression on the mesial surface of the mandible). Thus, they decided to investigate the presence of bifid mandibular canals in a sample of 84 individuals. The results demonstrated that the presence of these canals was detected with statistically significant difference when CBCT and panoramic radiographic images were compared. This suggests that the cone-beam system improves the diagnosis and prognosis of the clinical and surgical procedures at the retromolar region and mandibular body [17].

The disadvantages associated with CBCT includes the radiation dispersion, the limited dynamics reaching, the minimum detail of the soft tissue, and the presence of the artifacts caused by some dental materials and implants [15].

Some authors believe that the ionizing radiation is the key parameter limiting the use of this examination and they recommend that at any phase of the treatment one must follow the ALARA principle. ALARA is the acronym for "as low as reasonably achievable". It is a safe principle for radiation safe aiming to the decreasing of the doses to patients and workers as well as the discard of remnants of radioactive materials employing all reasonable methods [25].

Conclusion

CBCT is an excellent diagnosis tool, offering significant advantages regarding to the quality and quantity of anatomic information. When 3D image is necessary, CBCT should be the method of choice always justified by an accurate indication. This will provide an adequate cost/benefit ratio both for the treatment and patient.

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