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Applicability of cone beam computed tomography in dentistry: literature review

Aplicabilidade da tomografia computadorizada de feixe cônico na odontologia: revisão de literatura

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ABSTRACT

Cone beam computed tomography (CBCT) is a conventional tomography's improvement, developed especially for the assessment of the maxillofacial region. CBCT produces three-dimensional images that allow its use in several areas of dentistry. The objective of this literature review is to show, based on the literature, the diversity of applications in the field of dentistry that such imaging has, highlighting its benefits and limitations in different dental specialties. The present study consists of exploratory research, carried out through a review of the narrative literature. The bibliographic survey was carried out by means of national and international journal articles, theses, dissertations and other publications, found in the digital library databases (Google Academic, BVS, Sciencedirect, Researchgate, Scielo, Wiley Online Library, Pubmed), from 2000 to 2020. The articles that precede these data were selected for their historical character on the proposed theme. It is concluded that dentists must be aware of the technological advances that occur in the field of dental imaging in order to manage diagnoses and treatments more efficiently, thus avoiding possible errors. CBCT demonstrates that it has multiple indications in different dental specialties, each case must be evaluated individually, analyzing the real need for its use. In cases where there is a need for its use, its cost-effectiveness is better than any disadvantage it may present.
Keywords: Cone beam computed tomography. Dentisty. Radiology.

RESUMO

A tomografia computadorizada de feixe cônico (TCFC) é um aprimoramento da tomografia convencional, desenvolvida especialmente para a avaliação da região maxilofacial. A TCFC produz imagens tridimensionais que permitem sua utilização em diversas áreas da odontologia. O objetivo desta revisão de literatura é mostrar, com base na literatura, a diversidade de aplicações no âmbito odontológico que tal exame imagenológico apresenta, ressaltando os seus benefícios e limitações nas distintas especialidades odontológicas. O presente estudo consiste em uma pesquisa de caráter exploratório, realizada por meio de uma revisão da literatura narrativa. O levantamento bibliográfico foi realizado por meio de fichamentos de artigos de periódicos nacionais e internacionais, teses, dissertações e outras publicações, encontradas nas bases de dados da biblioteca digital (Google Acadêmico, BVS, Sciencedirect, Researchgate, Scielo, Wiley Online Library, Pubmed), nos anos de 2000 a 2020. Os artigos que antecedem essa data foram selecionados por apresentarem caráter histórico sobre o tema proposto. Conclui-se que o cirurgião-dentista deve estar ciente dos avanços tecnológicos que ocorrem na área de imagenologia odontológica para gerir com mais eficiência os diagnósticos e tratamentos, evitando, assim, possíveis erros. A TCFC demonstra possuir múltiplas indicações nas diversas especialidades odontológicas, cada caso deve ser avaliado individualmente, analisando a real necessidade do seu uso. Nos casos em que há a necessidade de sua utilização, o seu custo-benefício é melhor que qualquer desvantagem que ela possa apresentar.
Palavras-chave: Odontologia. Radiologia. Tomografia computadorizada de feixe cônico.

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INTRODUCTION

On November 8, 1895, professor of physics Wilhelm Conrad Roentgen was carrying out experiments on the effects of cathode rays in a glass ampoule with positive and negative electrodes inside. When discharging an electric current into the tube, he observed a fluorescent glow originating from a barium platinocyanide plate, which was located next to it. Roentgen interposed several objects between the tube and the plate, but none were able to attenuate its luminescence, except for lead and platinum, which completely interrupted it. By holding these materials between the tube and the plate, he could visualize the bones in his own hand, then realized that he had discovered something that, until that moment, had not been registered. This discovery marks the beginning of the radiographic examination (Forrai, 2007).

Radiographic examination has established itself as an essential auxiliary method in dental diagnosis and planning. However, conventional two-dimensional (2D) radiographs have some limitations in their images, such as magnification and superimposition of anatomical structures, in addition to frequently occurring geometric and volumetric distortions in the final image. All these limitations, presented by the two-dimensional image, make it impossible for the dental surgeon to make an indisputable diagnosis (Rodrigues, Alarcón, Carraro, Rocha & Capelozza, 2010).

Throughout history, it was sought how it would be possible to obtain three-dimensional images, since two-dimensional images are limited. In 1972, Hounsfield and Ambrose developed a prototype of what would become computed tomography (CT) (Carvalho, 2007). CT has become increasingly used for dental diagnosis, however, it had some limitations, such as: not allowing the visualization of dental elements in cross sections and the examination's long duration, therefore, the patient was exposed for a considerable time to a high dose of radiation (Fukai, Keisuke & Shigenobu, 1986).

In the 1990s, with the limitations presented by CT for the craniofacial region, it was decided to improve it, which led to the development of a tomograph focused to the dental area, based on the cone beam technique, called cone beam computed tomography (CBCT). This being capable of producing good quality three-dimensional images with a lower radiation dose (Mozzo, Procacci, Tacconi, Martini & Andreis, 1998; Hayashi et al., 2018).

Since the development of CBCT, its technology has had a rapid evolution, in part, prompted by the particularities and needs of each dental specialty (Moura et al., 2018). It allows the dental surgeon to accurately assess craniofacial morphology, bone and dental fractures, endodontic and maxillofacial lesions, anatomy and pathologies involving the temporomandibular joint (TMJ), carrying out orthodontic planning, among others (Araujo, 2019).

The present work seeks to show, based on the literature, the diversity of applications, in the dental field, that this imaging exam presents, emphasizing its benefits and limitations in different dental specialties.

MATERIAL AND METHODS

In order to carry out this literature review, scientific articles and books related to Cone Beam Computed Tomography and its applications in dentistry were researched. This search included the library collection and online databases Google Scholar, BVS, Sciencedirect, Researchgate, Scielo, Wiley Online Library, Pubmed, Bireme and CAPES Journals. The descriptors used to search for articles vary according to the theme of each dental area. The main descriptors used to search the articles were: "Cone beam computed tomography", "dentistry", "CBCT", "cone beam computed tomography" and "CBCT".

The inclusion criteria were: articles published in Portuguese and/or English, indexed between the years 2000 and 2020. The articles before that date, used in this review, were selected because of their historical character on the proposed topic. Exclusion criteria were: articles that did not have clinical or historical relevance and that did not follow the inclusion criteria.

In total, 964 articles and 3 books were analyzed. After reading the abstracts, 140 articles and 3 books were selected, which later went for an analysis, following the inclusion and exclusion criteria. The final sample consists of 1 book and 64 articles, of which 7 articles were found using Google Scholar, 5 from BVS, 6 from Sciencedirect, 1 from Researchgate, 7 from Scielo, 6 from Wiley Online Library and 32 from Pubmed.

RESULTS AND DISCUSSION

History of cone beam computed tomography

Throughout history, there has always been a curiosity to know what the inside of the human body would be like, without the need for surgical intervention. The discovery of x-rays made it possible to obtain two-dimensional images of the human body, however, these images lead to the loss of many anatomical details, due to their three-dimensionality (Carvalho, 2007).

Hounsfield, an engineer at EMI Ltd. (Electro Mechanical Installations Limited – UK), was developing a computer capable of analyzing the interior of three-dimensional objects, when Ambrose, a neuroradiologist, questioned whether it would be possible to see or observe the cranial interior. Then, in 1972, Hounsfield created a prototype of what would become the CT scanner. The image acquisition time took 9 days and its processing 150 minutes. Improving this prototype, Housfield coupled a tube and an x-ray generator, reducing the image acquisition time to 9 hours (Carvalho, 2007).

When the tomograph started to be marketed, a minicomputer was added to the system, which reduced the time to obtain each slice to 6 minutes and to reconstruct the image to 2 minutes. In Brazil, the first CT scanner was installed in São Paulo, in 1977, at the Hospital da Real e *Benemérita Sociedade Portuguesa de Beneficência* (Carvalho, 2007).

Over the years, devices have evolved, producing better images in less time and at a lower production cost. When comparing the numbers of modern CT scanners with those of the first generation, it becomes clear how much technology has evolved. In 1980, it was already possible to obtain high quality images and display them almost instantly (Beckmann, 2006).

In the 1980s, CT began to be used more and more in the field of dentistry, however it had some limitations, such as the very long examination time, high radiation dose and the impossibility of visualizing the teeth in cross sections. Most of these problems were solved with the use of two dimensions of international detection, a detection system with a cone beam, which used an image intensifier and a TV camera, called fluoroscopic tomography (Fukai et al., 1986). In the study by Fukai et al. (1986), it was found that the radiation exposure of fluoroscopic CT was approximately 10 to 20 times lower than that of conventional tomography. Another advantage was to visualize the shape of each tooth without overlapping other anatomical structures.

In the late 1990s, Pierluigi Mozzo and Yoshinori Arai developed a tomograph focused at the dental field, based on the cone beam technique. The first one named his machine as NewTom-9000, it used a cone-shaped X-ray beam and had a device that made it possible to control the size of its beam (Mozzo et al., 1998). Arai produced his machine from a Scarona brand x-ray unit (Soredex, Helsinki, Finland), called ORTHO-CT, which sought to provide a high-quality image with the lowest level of radiation possible (Hayashi et al., 2018; Manzi et al., 2018).

The CBCT is an improvement over conventional medical tomography, known as computed tomography. It was developed especially for the maxillofacial region, with the function of producing three-dimensional images of its anatomical structures (Nasseh & Al-Rawi, 2018).

Since its implementation in the dental scenario in the 2000s, the number of CBCT machines in dental hospitals, private clinics and radiology centers have increased exponentially around the world (P. P. Jaju & Jaju) due to its potential to improve the service provided and its several benefits offered to different dental areas (Araujo, Barros, Lopes, Silva & Freitas, 2019).

CBCT then became an image acquisition method with numerous indications in dentistry. It provides the dental surgeon with an improved diagnosis for numerous clinical applications, in addition to exposing the patient to a lower radiation dose compared to conventional computed tomography (Dula et al., 2014).

Cone beam computed tomography

CBCT is a cone beam scanning system that emits a cone-shaped x-ray beam that radiates a large area and not just a thin slice like a CT. This allows the equipment to perform just one turn and obtain the information needed to reconstruct the region of interest (ROI) (Nasseh & Al-Rawi, 2018).

There are several models of CBCT devices, a characteristic that differentiates them is the patient's positioning during the exam, with most being done with the patient standing or sitting, and it can also be in the supine position (Nasseh & Al-Rawi, 2018) The examination time should be as short as possible, 20 seconds or less being recommended, thus minimizing the risk of a patient moving (Hayashi et al., 2018).

The machine has an x-ray tube and a two-dimensional sensor that rotates synchronously from 180º to 360º around the patient's head, to acquire the data that will form the final image. If the CBCT rotates 180º, the examination time and radiation dose will be smaller, but the image quality will be lower than the image acquired by 360º rotation (Hayashi et al., 2018).

Image resolution also relates to field-of-view (FOV) size. The higher the FOV, the greater the area exposed to radiation and the lower the definition of the image. The data acquired during the exam are called two-dimensional projections (Dawood, Patel & Brown, 2009).

After acquiring the images, the two-dimensional projections are digitized by a specialized software, which uses reconstruction algorithms to convert them into three-dimensional data, resulting in the production of a digital volume. Voxels are the smallest subunit of a digital volume; determined prior to acquisition of tomographic slices, and can be modified to obtain images with greater sharpness and contrast. They are isotropic, which means that they have equal height, width, and depth dimensions. They are usually reconstructed in orthogonal orientations, as they allow the visualization of images in the coronal, axial and sagittal planes (Dawood et al., 2009; Hatcher, 2010; Simões & Campos, 2014).

Smaller voxels form higher quality images, however, the disadvantage of reducing voxel size is the need to increase the milliamperage (mA) and scan time, which leads to greater radiation exposure and longer rendering time (Torres et al., 2010; Simões & Campos, 2014).

The voxels, when combined, form the tomographic slices, which can be rendered and visualized in many angles (Dawood et al., 2009; Hatcher, 2010). Errors during the acquisition and processing of CBCT data can result in inaccurate images, erroneously influencing diagnosis and therapeutic decision-making (Bueno et al., 2020). The computer exports the image files in DICOM (Digital Imaging and Communications in Medicine) format, which is the universal digital format for images in the medical field, standardized by ISO (International Organization for Standardization) (Meurer et al., 2008; Abramovitch & Rice, 2014).

The limitations of CBCT are device's high cost, the radiation's dose to which the patient will be exposed, the inability to reproduce soft tissue, in addition to the possibility of the image being affected by different types of artifacts (such as dispersion, noise, hardening by beam, among others) (Ahmad, Jenny & Downie, 2012; Jacobs, Salmon, Codari, Hassan & Bornstein, 2018).

Artifacts are capable of significantly affecting the quality of CBCT images, as they cause less contrast in adjacent structures and can lead to an inaccurate diagnosis. Dense metallic structures are often the source of image artifacts in CBCT reconstructions. Artifacts are presented as light stripes, dark stripes, or darkening of edges adjacent to metallic edges. Dark stripes commonly resemble recurrent carious lesions or fractures in endodontically treated teeth, white stripes degrade image quality and overlap the existing anatomy in the region (Abramovitch & Rice, 2014).

Although CBCT exposes patients to a lower radiation dose than conventional tomography, its widespread use has resulted in concerns regarding the justification and optimization of radiation exposures. When choosing the cases in which it will be used, care must be taken so that material and financial resources can be used for the benefit of the patient, seeking to minimize the radiation dose as much as possible, following the ALARA principles "As low as possible" (the low as reasonably achievable) (Sedentexct, 2012; P. P. Jaju & Jaju, 2015).

When introducing the ALARA principle, one must understand that reducing the radiation dose to extremely low levels can render diagnostic images classified as useless. Consequently, the ALARA principle was modified to emphasize the importance of image quality, giving equal weight to quality and dose. The new concept made ALARA “as low as diagnostically acceptable” (P. P. Jaju & Jaju, 2015).

Image optimization aims to achieve a balance between radiation dose and image quality, in accordance with the recently introduced ALADAIP principle, which means “as low as diagnostically acceptable with targeted and patient-specific indication” (Oenning et al., 2018).

Statements published by the American Dental Association (ADA) and the European Academy of Dental and Maxillofacial Radiology (EADMFR) state that the dental surgeon who prescribes, performs, or interprets the CBCT exam must have adequate training and education in CT imaging. The prescription of CBCT in dental treatment should be performed when the risks associated with the potential dose of radiation absorbed by the patient are outweighed by the benefits that the exam will provide for diagnosis and treatment (Hatcher, 2010; American Dental Association, 2012; Brown et al., 2014).

Clinical applications of cone beam computed tomography in dentistry

Within the dental areas, the one that most used CBCT was implant dentistry. However, with the evolution of technology and its benefits, it has been increasingly requested by different areas, as it allows the dentist to verify the bones’ morphology of the face, in addition to various diseases, dental and bone trauma, maxillofacial injuries and endodontic, impacted teeth, TMJ changes, among others (Rodrigues et al., 2010).

Applications of cone beam computed tomography in surgery

In oral surgery, CBCT can be indicated for extraction of third molars, impacted teeth, supernumerary teeth, planning of orthognathic surgery and implants, diagnosis of bone and dental fractures, alveolar canal location, TMJ evaluation and post-surgical follow-up of lesions with high relapse rate (Ahmad et al., 2012).

The impacted lower third molars, when close to the mandibular canal, present a risk of damage to the nervous vasculature bundle during its extraction. Panoramic radiography is usually used in pre-surgical evaluation. In its image, the presence of Rood's criteria should be analyzed, such as darkening of the root apexes of the tooth, interruption of the radiopaque line of the mandibular canal and its deviation, which suggests the proximity of the tooth to the mandibular canal (Ferraz et al., 2019). However, the 2D image of the panoramic radiograph shows superimposition of anatomical structures, therefore, when the proximity of the third molar with the mandibular canal is noticed, the three-dimensional examination must be requested (Matzen & Wenzel, 2015). The possibility of injuring the inferior alveolar nerve in the trans-surgical procedure is greater when the exact location of the tooth is not known, which can cause a picture of paresthesia in the patient (Ganz, 2011).

The images of the three-dimensional exam reveal the correct relation of the tooth with the adjacent anatomical structures, due to tomographic sections in different spatial planes (Matzen & Wenzel, 2015). It should be noted that, regardless of whether the panoramic radiograph image does not meet Rood's criteria, the tooth may still be in contact with the mandibular canal, thus validating the CBCT request (Nakamori et al., 2008).

Given the fact that CBCT generates cross-sectional images in cases of cleft palate, it allows the assessment of cleft width and extension, in addition to its relation with adjacent teeth (Ahmad et al., 2012). This essential knowledge of the morphology of cleft palate results in better planning and surgical management, providing a better prognosis (Wortche et al., 2006).

Orthognathic surgery performed to correct dentofacial skeletal discrepancies results in improved esthetics and patient occlusion. Pre-surgical planning becomes more in line with reality when done through 3D documentation. This planning facilitates the choice of the most appropriate treatment, combining aesthetic and functional results. During the stages of making plaster models and conventional radiographs, distortions can occur and the accuracy of measurements is not incompatible, especially in more complex cases, such as facial asymmetry. Therefore, CBCT helps to obtain three-dimensional models of the skull and makes its assessment accurate (Leal & Moreira, 2013).

Through the combination of imaging exams, such as magnetic resonance imaging (MRI), CT, CBCT and CAD (Computer-Aided Design) and CAM (Computer-Aided), it became feasible to create a virtual patient faithful to the characteristics of the real individual. This reconstruction allows the dentist to simulate the surgery, virtually, and the post-surgical result of the case, not requiring previous laboratory activities (Leal & Moreira, 2013).

In the dental field, biomedical prototypes can be used in maxillofacial surgery and traumatology, implant dentistry, oral rehabilitation and orthodontics. They allow the construction of physical models that faithfully reproduce the craniofacial anatomy, in addition, they allow the full visualization of lesions and adjacent tissues, planning the entire surgical act, including the previous conformation of biomaterials, thus reducing surgery time. For the acquisition of these biomodels, the imagenology area is associated with CAD/CAM software (Freitas, Costa & Ribeiro, 2010; Safira et al., 2010).

After image acquisition, the data is transferred to a computer, where it will be manipulated to acquire the model that will be printed. Afterwards, the file will be converted to a new format, as the CBCT image format cannot be processed by the 3D printer. The converted files, when printed, will originate the biomodel. As limitations, biomedical prototypes have a high cost and time-consuming execution. However, its use influences positively, reducing surgical time and increasing the procedure success rate (Meurer et al., 2008).

Applications of cone beam computed tomography in Endodontics

Periapical radiographs are the most common exam used to obtain an image of the interior of the root canal and periapical tissues. As this is a 2D examination of a 3D structure, the dental surgeon may be led to overestimate the real length of the root canal and the correct position of the apical foramen (Oliveira et al., 2017).

Therefore, CBCT applications in endodontics include visualization of the anatomy of the root canal, identification and location of internal and external resorptions, detection of vertical root fractures, surgical planning, diagnosis of incipient lesions, also providing accurate measurements of the working length during endodontic treatment (Tyndall & Kohltfarber, 2012; Oliveira et al., 2017).

During endodontic opening, the dental surgeon needs to visualize the root canals and handle them to carry out the endodontic treatment, without unnecessary wear and tear on the remaining tooth structure (Clark & Khademi, 2010). In cases in which the root canals are calcified, endodontic treatment becomes tiring. Guided endodontics (Endoguide) emerged as an alternative treatment for more complex cases (Meer et al., 2015).

To make an "Endoguide", a few steps are necessary. First, it is necessary to obtain CBCT images and intraoral scanning to make virtual plans, which will determine the depth, width, angulation and location in which the drill for the referred case will be used for endodontic opening, thus, being possible to print the access guide on a 3D printer (Connert et al., 2018).

As a disadvantage, guided endodontics has some limitations, such as the need for a straight-line access between the root apex and the pulp chamber and limited access to the posterior region of the arches. On the other hand, this technique provides ease of execution, agility in opening and locating root canals and reducing the possibility of perforations. Due to less wear on the tooth structure, the technique also generates greater stability for endodontically treated teeth, which reduces the risk of fractures (Connert et al., 2018; Connert et al., 2019).

Applications of cone beam computed tomography in Implantology

Dental implants are the ideal choice for replacing lost elements. Implant dentists who use CBCT to plan their clinical cases do so more accurately because it provides reliable measurements of width, height, thickness, and bone quality (Al-Ekrish, 2018).

The American Academy of Oral and Maxillofacial Radiology (AAOMR) recommends the visualization of the implant recipient region through a transverse image, as it ensures, with precision, the simultaneous visualization of bone height and width (Tyndall et al., 2012).

When planning the placement of implants, some authors stated that a clinician requires information about: structure, topographical density and bone volume and their relation with important anatomical structures such as nerves, blood vessels, dental roots, nasal floor and sinus cavities or any clinical pathology relevant. Consequently, CBCT is indicated as a preoperative exam in implant dentistry (Tyndall et al., 2012; Bornstein et al., 2018).

In the planning phase, CBCT provides information on the location, size and angulation of the implant body, the need for bone graft or removal, and the relation of the implant with anatomical structures (maxillary sinus, nasal cavity and neurovascular canals). This information helps to avoid possible trans or post-surgical complications, such as paresthesia resulting from compression or partial or total disruption of nerves in the maxillofacial region (Ganz, 2011; Al-Ekrish, 2018).

Postoperatively, CBCT can be used to observe the relation of the implant with the surrounding bone tissue and anatomical structures. Although, it should only be used after complex surgical procedures, which require follow-up, in cases where there were bone reconstruction or augmentation, when there is proximity of the implant with nervous vasculature structures or post-surgical complications (Deeb et al., 2017; Jacobs, 2018).

Three-dimensional images can also be useful to diagnose and treat possible postoperative complications, such as infections related to dental implants inserted close to sinus cavities (Bornstein et al., 2018).

In the absence of post-surgical complications, follow-up can be carried out with periapical radiographs, and, in cases of multiple implants or prostheses, the recommended protocol is to perform a panoramic radiograph, as both have 3 to 6 times lower radiation dose to that the patient will be exposed, when compared to CBCT (Tyndall et al., 2012; Kottou et al., 2018).

Applications of cone beam computed tomography in Periodontics

The radiographic exam is an essential way to diagnose and plan in periodontics, however, intra and extraoral radiographic techniques offer limited images in only two planes: superior-inferior and postero-anterior, in addition to small geometric and volumetric distortions in the final image, influencing the size and detection of bone defects. Through 2D images, it is not possible to measure the buccolingual width (VL) of the bone defect, only the height and the mesiodistal distance (MD) can be measured (Caputo et al., 2009; Rodrigues et al., 2010; Li, Jia & Ouyang, 2015).

CBCT's ability to visualize alveolar bone in 3D and take measurements at any location has the potential to significantly improve periodontal diagnosis. The use of 3D and 2D images for the evaluation of artificial bone defects showed that CBCT has a sensitivity of 80% to 100% in detecting, classifying and identifying bone defects, while intraoral radiographs have a sensitivity of 63% to 67% (Fuhrmann; Bucker & Dierich, 1995; Misch, Yi & Sarment, 2006).

CBCT allows the visualization and location of bone defects and furcation lesions, unlike conventional radiography, which has the limitation of not allowing visualization of the periodontal bone level and the lamina dura. When it is not possible to diagnose and plan the treatment of periodontal lesions using conventional radiographic methods, CBCT can be requested. High quality images sometimes require a higher dose of radiation; in order to reduce this exposure, the use of a small FOV is indicated (Dawood et al., 2009; Acar & Kamburoglu, 2014).

CBCT provides greater security and precision in periodontal surgical planning, and also influences the choice of the best surgical techniques and superior biomaterials in different situations. In cases of gummy smile, detailed visualization of the relation between the cementoenamel junction and the alveolar bone crest allows a better prognosis (Souza, Costa & Vidal, 2016).

The latest European guideline shows that there is a lack of scientific basis to indicate the routine usage of CBCT in cases of periodontal patients (Sedentexct, 2012). As Kim and Bassir (2017) demonstrated, when the radiation dose and the cost of the exam are reduced, CBCT may be more requested in the area of periodontics. However, when surgical intervention is needed or when dealing with complex procedures, its use is justifiable (Souza et al., 2016).

Applications of cone beam computed tomography in Orthodontics and in the evaluation of the temporomandibular joint

The AAOMR suggests the following guidelines for the application of CBCT in orthodontics: analyze the risk of radiation dose, select adequate FOV according to clinical need, reduce radiation exposure and only trained professionals must perform and interpret the exam. The CBCT allows the orthodontist to view all the images that make up the orthodontic documentation in just one exam (AAOMR, 2013; Garib et al., 2014).

CBCT data are rendered in orthogonal planes, however, the software makes it possible to visualize the airway space, assess the maxillofacial region and the structures that compose it. It is used in several cases, such as: anomalies in dental position and/or structure, facial asymmetry, skeletal and dental discrepancies, assessment of bone expansion procedures, TMJ signs and symptoms, craniofacial anomalies, among others (AAOMR, 2013).

CBCT is of great value in diagnosing impacted teeth. Its three-dimensional image provides details on the location of the crown and root apex, their relation with adjacent teeth, the orientation of the long axis of the tooth and orthodontic traction (Pavoni, Mucedero, Laganà, Paoloni & Cozza, 2012).

According to Matzenbacher, Campos, Pena e Araújo (2008), cone beam computed tomography is the most accurate imaging exam to evaluate the vertical position of the chosen points for placement of mini-implants for orthodontic skeletal anchorage.

To visualize the bone structures that make up the TMJ without image overlapping and distortion, CBCT is the most indicated exam. For soft tissue analysis, MRI should be used. CBCT accurately detects bone changes, such as remodeling, erosion, flattening and ankylosis present in the condyle, temporal fossa or joint eminence (Alexiou, Stamatakis & Tsiklakis, 2009; Barghan, Merrill & Tetradis, 2012).

Even though CBCT allows professionals to visualize fundamental information about bone morphology, it is not the standard method of diagnosis in orthodontics, as it exposes the patient to a higher dose of radiation when compared to conventional radiographic exams. It is needed to balance the cost-benefit ratio of each case, and to be requested when there is evidence that new information will be added and that it may change the treatment plan (Garib et al., 2014).

Applications of cone beam computed tomography in Dental Radiology

Two-dimensional images are limited by the superposition of anatomical structures, so they may not provide all the information needed for an accurate diagnosis of lesions. Another limitation of the two-dimensional examination is the inability to accurately visualize the lesion margins. A benign-appearing lesion, when seen on CBCT, may have a malignant character, as the tomographic sections allow observing the irregular margins of incipient lesions (Ahmad et al., 2012).

The 3D image provides the assessment of bone lesions, their proximity to anatomical structures, presence and extent of bone resorption, cortical expansion and internal or external calcifications. It also favors the post-surgical follow-up of lesions with a high rate of recurrence, as it allows full visualization of their margins. When needed to evaluate soft tissues, MRI is the exam of choice (Ahmad et al., 2012).

Benign tumors are evaluated on 2D and 3D imaging; each one demonstrates different characteristics of the lesion. There is usually difficulty in interpreting conventional radiographic exams, as sometimes the images are superimposed on anatomical structures. However, CBCT clearly expresses the margins of the lesion and its relation with the surrounding structures (Alcantara, Pagin & Capelozza, 2018).

To correctly assess the bones affected by neoplasms or malignant tumors, CBCT proves to be useful. It also helps preoperatively, measuring the necessary extension of the resection, generating a tumor-free safety margin (Closmann & Schmidt, 2007).

Imaging exams are essential to establish a presumptive diagnosis and help in choosing the clinical approach, reducing the likelihood of complications for the patient. For this reason, the dental surgeon needs knowledge and training in the interpretation of both 2D and 3D images, with the final diagnosis being determined by the histopathological examination (Alcantara et al., 2018).

Applications of cone beam computed tomography in Forensic Dentistry

Medical examiners use different methods to identify disfigured bodies, such as chronological age, height, and sexual dimorphism. Anthropometric techniques usually make use of the pelvis and skull to identify decomposed bodies. However, in some cases, it is not possible to use the pelvis, as it is absent or fragmented. For this reason, structures of the dentomaxillofacial complex have been used for the analysis of human identification (See et al., 2009; Angel, Mincer, Chaudhry & Scarbecz, 2011).

The record of dental conditions, such as changes in dental eruptions, presence of malocclusion, previous dental treatments, changes caused by age and growth disorders make the mouth of each individual unique, therefore, they are essential in the process of identifying bodies (Valenzuela, Martin-de las Heras, Marques, Exposito & Bohoyo, 2000).

CBCT applications are in the head and neck regions, consequently, in forensic anthropology, it is used in identifications, through the dental arches and paranasal sinuses (Sarment & Christensen, 2014). Teeth are formed by the most resistant tissues of the human body, even at high temperatures they remain almost unaffected, as they are protected by the musculature and bone structures involved in lip sealing (Woisetschläger, Lussi, Persson & Jackowski, 2011).

With the CBCT, it is also possible to observe the path taken by the projectile in injuries caused by firearms, in addition to the distance and direction of the shot. When CBCT is compared with multi-detector computed tomography, it is observed that the path inside the body can be seen with minimal interference from metallic artifacts caused by the bullet fragments (See et al., 2009).

CBCT is gaining more space in this area, as it is easier to transport, radiates a lower dose of radiation when compared to conventional CT, provides faster results and simpler training for its operation (Sarment & Christensen, 2014).

CONCLUSION

To conclude, CBCT shows that it has multiple indications in different dental specialties. Its quality is the production of images with coronal, axial and sagittal slices; therefore, it reliably reproduces anatomical structures in three-dimensional images. Its angulations make it essential to perform diagnoses and treatments that require accurate visualization. CBCT, as long as it is well indicated and performed, is an excellent auxiliary diagnostic and planning method in Dentistry.

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