Cone-Beam Computed Tomography in Dental Practice: Literature Review and Own Observations

Yuliia L. Korobeinikova[1]*, Leonid S. Korobeinikov[2]

1. Department of propaedeutics of orthopedic stomatology, Poltava State Medical University, Ukraine.

Abstract

A cone-beam computed tomography (CBCT) is a diagnostic method that provides radiographic visualization with an accurate three-dimensional (3D) image of hard tissue structures. CBCT is a modern diagnostic method in dentistry that promises many advantages in the near future, and the possibilities of its use are almost unlimited, provided that it is prescribed reasonably and appropriately.

The purpose of this article is the review the possibilities of using cone-beam computerized tomography in dental practice, taking into account the advantages and disadvantages, with illustration of specific clinical cases.

The main cases of CBCT usage in dentistry are endodontics, implant planning, orthodontics and orthopedics, diseases of the temporomandibular joint. The article is justified on the basis of literary sources and on the basis of own observations of the use of KPKT in various fields of dentistry, the most significant examples of the use of this diagnostic method, limitations in certain cases and prospects for future use are given.

CBCT method is of primary importance for diagnosis, treatment planning and direct selection of the root canal treatment method. It also has undeniable advantages in diagnosing complications in endodontics. CBCT should not be the «gold standard» in orthodontic practice, but should be used only in cases of difficult diagnosis or treatment optimization. CBCT may be justified for preoperative diagnosis, planning, and postoperative rehabilitation, on condition of optimization hardware-dependent, specific, and nonspecific factors that may affect the quality of diagnosis. CBCT may be justified for preoperative diagnosis, planning, and postoperative rehabilitation, on condition of optimization hardware-dependent, specific, and nonspecific factors that may affect the quality of diagnosis. It is also important to use different modes, viewing images in different planes in each case, but with the obligatory justification of their expediency.

This brief review summarizes the knowledge of CBCT use in various fields of dentistry and will be useful for practicing dentists, as it is accompanied by illustrations of specific cases from practice.

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Introduction

Radiological diagnostic techniques are among the most important in the diagnostic evaluation of patients with suspected diseases of the teeth and maxillofacial area. Combinations of simple X-ray projections and panoramic images may be sufficient in some clinical situations, but computed tomography can facilitate the assessment of pathological changes. One of these methods is a cone-beam computed tomography, which provides multi-plane imaging [1]. Images obtained with this technology are a popular diagnostic imaging method in various fields of maxillofacial pathology and their use is constantly growing [2].

A cone-beam computed tomography (CBCT) is a diagnostic method that provides radiographic visualization with an accurate three-dimensional (3D) image of hard tissue structures

***Corresponding author:**
Yuliia Korobeinikova
36011, Poltava, Shevchenko str. 23, PDMU,
Department of propaedeutics of orthopedic stomatology.
E-mail: yu.korobeinikova@pdmu.edu.ua

[3]. CBCT provides the ability to view a single tooth or several teeth from different angles, not just the default one, which ensures a complete diagnosis, choice of treatment and follow-up of the patient [4]. CBCT has both advantages and disadvantages over traditional CT. The advantages include lower effective radiation doses, lower costs, easier image acquisition and interactivity (e.g., multiplanar reconstruction). The disadvantages of CBCT are the inability to visualize soft tissue pathology; limited quantification of bone density; and the presence of various types of image artifacts [5].

Therefore, the research of this imaging method in dentistry remains relevant, and the development of criteria for its use is a prerequisite for the selection of radiological diagnostics in each individual case.

This article discusses the current achievements in the use of CBCT in dental practice.

The purpose

The purpose of this article is the review the possibilities of using cone-beam computerized tomography in dental practice, taking into account the advantages and disadvantages, with illustration of specific clinical cases.

Brief historical background and technical characteristics

In 1984, Feldkamp first demonstrated the cone-beam algorithm for tomographic reconstruction of two-dimensional projection images, which was developed specifically for the study of the maxillofacial area. However, for 15 years, CBCT devices could not enter the market due to the lack of sufficient technical capabilities[5,6].

CBCT lies in circular or rectangular radiation of a cone-shaped X-ray beam 360° around the vertical axis, with simultaneous movement of the X-ray source and reciprocating detector array around the patient's head, which is fixed with a holder. Projection data is generated from the base images, which are converted into three-dimensional images using software. The latter are used for reconstruction in the axial, sagittal and coronal planes. With the help of CBCT, the images with a resolution of 2 line pairs/mm can be obtained with a scanning time of approximately 60 seconds. The radiation dose at CBCT is only 68 μSv compared to 600 μSv at usual CT [3,7,8].

The use of CBCT in therapeutic dentistry

The cone-beam computed tomography in restorative dentistry can be used for a variety of purposes, including diagnosis, treatment planning, and evaluation of treatment outcomes. CBCT can also be used to detect any potential complications, such as root resorption or implant failure [2,9].

The main cases of CBCT usage in dentistry:

- In endodontics, CBCT can be used to determine the exact location of root canals in the tooth, which can help the dentist clean and fill the canals more efficiently.

- Implant planning: CBCT can be used to create a detailed 3D image of the patient's jaws, allowing the dentist to accurately assess the amount of bone available for implant placement and accurately plan the implant placement.

- Orthodontics and orthopedics: CBCT can be used to create a 3D model of a patient's teeth and jaws, which can be used to plan orthodontic and orthopedic treatments and monitor their effects and complications.

- Diseases of the temporomandibular joint (TMJ): CBCT can be used to create a detailed 3D image of the TMJ, allowing the dentist to accurately diagnose and treat the disease.

The use of CBCT in endodontics.

The use of CBCT in endodontics is widely used all over the world and is one of the leading diagnostic methods in difficult cases [10,11], which has a number of advantages over traditional radiography [4]. CBCT allows to identify and visualize additional and lateral canals, perforations, obturations, determine the shape of the canal and vertical root fractures, and establish the full length of the root canal [12]. Radiological diagnostics in therapeutic dentistry includes an examination of the quality of root canal filling. CBCT has a great importance in the diagnosis of complications associated with the root canal filling procedure when using various obturation methods [13, 14].

One of these complications is the development of odontogenic cysts (Fig 1). In our observation, we can see that due to poor-quality root canal filling (obturation not to the apex), formed a cystogranuloma at the apex of the root. Thanks to CBCT, it is possible to objectively determine its parameters, since digital 3D radiography allows us to take measurements in

three planes - axial, sagittal, and frontal.

CBCT allows visualization of the size, borders, condition of surrounding tissues and the presence of cyst contents, even when the lesion overlaps with adjacent bone structures. They can also be used to assess the size and contour of pre- or postoperative deformities during tumor resection and help determine the amount of bone needed for a reconstructive procedure [15]. Therefore, the diagnosis of cystic formations prior to treatment is extremely important, as based on the data from CBCT, the doctor may choose a completely different treatment tactic.

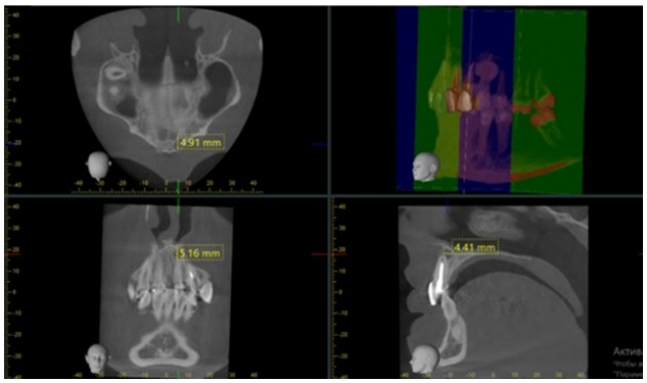

Figure 1. Cyst at the apex of the tooth root 21. CBCT, sagittal projection.

Figure 2. Multiplanar reconstruction of a three-plane CBCT image. Odontogenic sinusitis as a result of poor-quality root canal filling of tooth 27.

Odontogenic sinusitis is one of the most common diagnostic aspects of dentistry. According to current data, odontogenic maxillary sinusitis accounts for 25-40% of cases. The incidence of odontogenic sinusitis is constantly growing, and the diagnosis is often made with a delay, which leads to inadequate and unsuccessful treatment [16,17]. Therefore, when planning the treatment of teeth in the upper jaw, an important diagnostic point is the examination of the maxillary sinuses, since some roots of the teeth in the upper jaw may be located directly in the sinus. It is CBCT that is much more informative than traditional radiography in detecting dental diseases that cause sinusitis [17,18].

Here is a case of odontogenic sinusitis that arose as a result of poor-quality root canal filling of the 27th tooth, which led to the formation of a cystogranuloma with subsequent destruction of the cortical bone plate and impaired pneumatization of the maxillary sinus (Fig 2).

In addition, this patient clearly shows bone resorption around the root of the affected tooth, which was detected by CBCT (Fig 3).

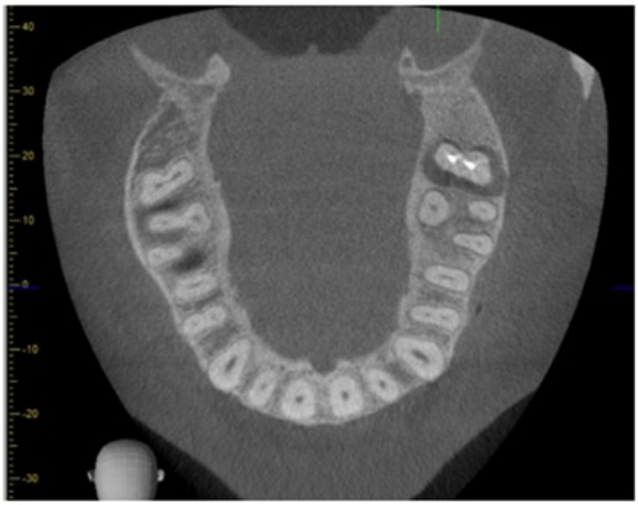

Figure 3. CBCT, axial projection, tooth 27. Destruction of bone tissue around the tooth root.

So, CBCT is a primary importance method for diagnosis, treatment planning and direct selection of the root canal treatment method. It also has undeniable advantages in diagnosing complications in endodontics.

The use of CBCT in orthodontics.

For an increasing number of orthodontic patients, the understanding of the complex anatomical interactions and surrounding structures of the maxillofacial skeleton is essential for orthodontic planning and for selecting the most appropriate therapy from a wide range of available treatment options [19].

CBCT images contain isotropic voxels, so each element of the object under study has the same dimensions in all orthogonal planes. This allows to create the accurate multi-plane images that are necessary for the practicing orthopedic

surgeon [20]. There is a clear list of indications for the CBCT use in orthodontics, but it is necessary to take into account its benefits in each case.

The selection criteria for any radiographic examination are based on clinical data, monitoring and evaluation of treatment outcomes, so the use of CBCT should be clearly justified [21], as two-dimensional radiographic methods, such as panoramic and cephalometric radiographs, are usually sufficient in orthodontics [22]. Therefore, CBCT should not be the «gold standard» in orthodontic practice, but should be used only in cases of difficult diagnosis or treatment optimization [23].

The majority of orthodontic patients are children, so orthodontists should adhere to the ALADAIP principle (expose to radiation as low as diagnostically acceptable being Indication-oriented and Patient-specific) [24, 25]. Ionizing radiation during CBCT can cause DNA damage and, as a result, cancer development, especially in children who have higher tissue radiosensitivity compared to adults [26, 27, 28].

The use of CBCT in orthopedics dentistry.

An important advantage of CBCT is that it provides images of various structures of the maxillofacial region in three planes and provides curved or flat images of different thicknesses (Fig 4 a). In addition, CBCT provides multi-plane reformatted images, volumetric visualization, maximum intensity projection, and other 3D visualizations [29] (Fig 4 b). In addition, CBCT is used to assess the condition of abutment teeth for metal-ceramic structures [30].

Figure 4. The use of CBCT in orthodontics: a - VR mode (volume rendering mode) in the projection of the 3D visualization window; b - MIP mode (maximum intensity projection) of the 3D visualization.

The most objective for orthopedic dentistry is the panoramic zonography window in cross-sectional mode, since we can view the summation panorama in the sagittal projection (Fig 5).

This image (Fig 5) visualizes the presence of orthopedic structures that do not meet generally accepted standards. And when replacing such structures, the orthopedic surgeon should also pay detailed attention to the condition of the maxillary sinuses. This image in the right segment visualizes the connection of tooth 16 with the maxillary sinus due to poor orthopedic treatment and subsequent formation of structural and functional changes in periodontal tissues. This led to a violation of the integrity of the cortical plate, and subsequently to odontogenic maxillary sinusitis, according to the radiologist's description.

Therefore, it is also important to use different modes, viewing images in different planes in each case, but with the obligatory justification of their expediency.

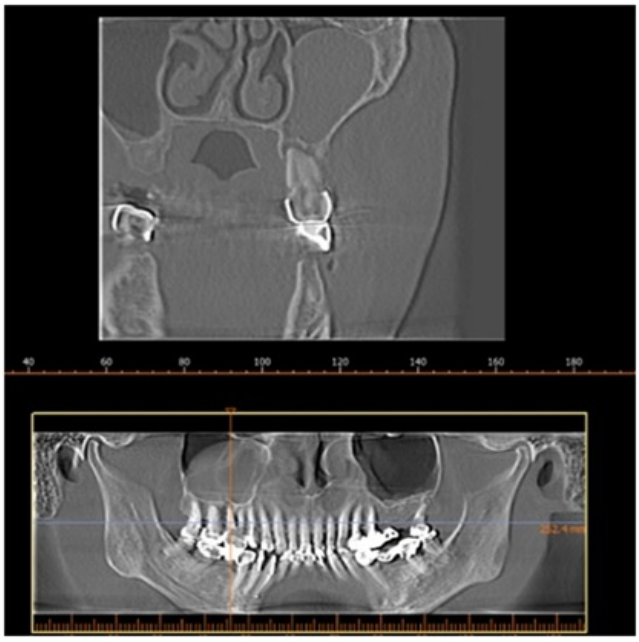

Figure 5. Volumetric panoramic zonography, cross-sectional mode of the sagittal plane from above.

CBCT for TMJ diseases.

The most common cases of CBCT use in TMJ diseases are intra-articular fractures, osteoarthritis and fibrocystic ankylosis, as well as TMJ hypoplasia [31, 32]. In addition, CBCT is important in the study of TMJ changes in malocclusion [33]. CBCT provides more reliable and accurate images of the TMJ than CT or panoramic radiographs [34].

Osteoarthritis is a non-inflammatory disease associated with age-related changes in

the TMJ and characterized by the development of changes in the bone that extend to the joint tissues with subsequent degeneration of the joint surfaces. CBCT provides detailed three-dimensional diagnostic images of degenerative changes in the TMJ with a lower dose and shorter exposure time, higher resolution compared to CT. CBCT shows in details the structure of the TMJ, flattening, osteophyte formation, erosion, reduction of the joint gap, sclerotic changes and cysts, and thus facilitating early detection of osteoarthritis, as well as monitoring of changes in this disease during treatment [35].

The most common causes of TMJ ankylosis are trauma, infections, rheumatoid arthritis, postoperative complications, and fractures of the process. In the diagnosis of ankylosis, CBCT can show partial or complete disappearance of the joint gap and bone tissue, the formation of osteophytes, the presence of calcifications, erosions, and remodeling of the condylar head [36]. Usually, plain radiography or limited CBCT is sufficient to detect condylar fractures in TMJ injuries, but multiplanar CBCT may be required to determine the extent of the condylar head fracture [37].

CBCT in implantation planning

When planning the placement of a dental implant, the initial step is to determine the anatomical structure of the jawbone that will support a properly placed implant. Determining the structure and density of the bone is an important diagnostic point in preoperative dental treatment. Usually, intraoral and panoramic radiography are used for this purpose, but CBCT is becoming increasingly important, as it has high resolution with a relatively low radiation dose, and the CBCT gray scale is becoming the standard for measuring bone density. The use of CBCT is mainly based on linear measurements of bone width and height and bone density [38, 39].

However, a safety margin of 2 mm for adjacent anatomical structures should be taken into account when using CBCT. The accuracy and reliability of measurements on CBCT images in clinical practice may be reduced due to patient movement, metal artifacts, specific device exposure parameters, and used software [40]. Therefore, CBCT may be justified for preoperative diagnosis, planning, and postoperative rehabilitation, on condition of optimization hardware-dependent, specific, and nonspecific factors that may affect the quality of diagnosis.

Conclusions

CBCT is a modern diagnostic method in dentistry that promises many advantages in the near future, and the possibilities of its use are almost unlimited, provided that it is prescribed reasonably and appropriately. This brief review summarizes the knowledge of CBCT use in various fields of dentistry and will be useful for practicing dentists, as it is accompanied by illustrations of specific cases from practice.

Declaration of Interest

The authors report no conflict of interest.

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