

# REVIEWS

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## Cone Beam Computed Tomography Imaging in Clinical Endodontics – Literature Review

### Obrazowanie metodą tomografii stożkowej w endodoncji klinicznej – przegląd piśmiennictwa

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A – concept; B – data collection; C – statistics; D – data interpretation; E – writing/editing the text;  
F – compiling the bibliography

#### Abstract

Cone beam computed tomography (CBCT) is widely used in dentistry due to low radiation, high-quality digital reconstruction of three-dimensional image, the elimination of the overlapping of structures which lie along the same axis, the possibility of obtaining real shaped images and enabling accurate measurements of the examined anatomical structures. Three-dimensional imaging of the structures of the stomatognathic system is most commonly implemented in endodontics, implantology and periodontics. The CBCT technique is used in endodontics primarily to detect anatomical abnormalities, visualise the root canal system, disclose additional canals, detect perforations and vertical root fractures, diagnose periapical lesions caused by inflammation of the pulp, identify and locate root resorption, clarify the reasons for the lack of healing of endodontically treated teeth. An important advantage of CBCT over conventional radiography is the fact that CBCT enables an exact visualisation of the structures which make the treatment more effective and predictable (*Dent. Med. Probl.* 2013, 50, 1, 78–84).

**Key words:** cone beam computed tomography, endodontics.

#### Streszczenie

Stożkowa tomografia komputerowa (CBCT) ma szerokie zastosowanie w stomatologii ze względu na: niską emisję promieniowania jonizującego, cyfrową rekonstrukcję wysokiej jakości trójwymiarowego obrazu, wyeliminowanie nakładania się na siebie struktur leżących wzdłuż jednej osi, wierne odwzorowanie rzeczywistego kształtu i możliwość wykonania precyzyjnych pomiarów badanych struktur anatomicznych. Trójwymiarowe obrazowanie struktur układu stomatognatycznego jest najczęściej wykorzystywane w endodoncji, implantologii i periodontologii. Technika CBCT w endodoncji jest stosowana do: wykrywania anomalii anatomicznych, wizualizacji systemu kanałów korzeniowych, ujawnienia kanałów dodatkowych, wykrywania perforacji i pionowych pęknięć korzeni, rozpoznania zmian okołowierzchołkowych spowodowanych zapaleniem miazgi, identyfikacji i umiejscowienia resorpcji korzeni, wyjaśnienia przyczyn braku powodzenia pierwotnego leczenia endodontycznego. Zaletą CBCT jest dokładność obrazowania pozwalająca na skuteczniejsze i bardziej przewidywalne przeprowadzenie leczenia (*Dent. Med. Probl.* 2013, 50, 1, 78–84).

**Słowa kluczowe:** stożkowa tomografia komputerowa, endodoncja.

Cone Beam Computed Tomography (CBCT), also known as Cone Beam Volumetric Tomography, is an imaging technique in which cone shaped beams of X radiation fall on a two-dimensional detector. This enables smaller surfaces to be

scanned faster. CBCT has also other advantages over conventional radiography. The amount of ionising radiation to which the patient is exposed is not significantly high (about 20 Sv), the whole process takes less time (a few seconds), and it is po-

ssible to obtain data during one spin of the tube. Moreover, one can acquire high-quality 3D images whose size, brightness and contrast can be edited, and the cost of this kind of imaging is much lower [1]. Furthermore, due to the fact that CBCT provides thousands of images in three planes (axial, sagittal and coronal), one can reconstruct accurate images showing the real size and shape of the structures without their overlapping even if they lie along the same axis. Images obtained during CBCT scans are also better than panoramic radiograms because they are not distorted. This, in turn, enables practitioners to make precise measurements in all dimensions. Therefore, it decreases the danger connected with surgical procedures; for instance, it eliminates the risk of damaging important structures, e.g. the inferior alveolar nerve. The first 3D diagnostic system for dental purposes was designed and produced in 1995 by the Italian company QR Inc. [1]. CBCT has been available for use in dentistry and maxillofacial surgery since 1998 in Europe and since 2001 in the USA [2]. However, at that time it was not widely used due to its high costs. Nowadays, CBCT is used in diagnosing and planning of the treatment of the lesions in the stomatognathic system and is used for determining the size and shape of structures such as temporomandibular joints, roots of the teeth, periapical bone tissue, the spatial structure of anomalies and pathologic lesions (exostoses, tumour-like lesions of the maxilla and mandible, cysts, supernumerary teeth), (3) the location of structures embedded in bone (paranasal sinuses, the canals of alveolar and dental nerves). These possibilities are used in many dental specialties. CBCT enables endodontists to evaluate the anatomy of teeth and periodontal structures, the number, shape, and location of root canals, or to detect dentinoids [3, 4]. CBCT is used in orthodontics in order to diagnose dental and occlusal anomalies, detect supernumerary or impacted teeth [5]. Periodontists use CBCT to evaluate the periodontium and the region of the furcation [6], whereas in implantology, CBCT enables dental implantologists to determine the thickness and other structural properties of bone in the places in which the implant is going to be placed, or locate the inferior alveolar nerve [7]. Maxillofacial surgeons make use of CBCT in examining tissues and structures of the stomatognathic system such as temporomandibular joints [15, 16], location and size of pathologic lesions, e.g. polyps in the maxillary sinus, salivary gland stones, cysts, odontomas, osseous fibromas [6].

According to up-to-date literature, CBCT should be chosen in difficult cases in which 2D images have proven ineffective [3]. Such difficult cases include:

- the presence of additional root canals, anomalies of root canal system and curvatures of the roots,
- the occurrence of mutually exclusive non-specific symptoms,
- wrong diagnosis during previous treatment,
- overlapping of images which cannot be overcome using 2D imaging techniques,
- the presence of non-endodontic pathologies,
- evaluation of complications occurring during or after the treatment,
- diagnostics of dento-alveolar trauma,
- location of root resorption,
- pre-treatment planning of periapical surgical procedures.

Using CBCT allows endodontists to visualize the root canal system, find additional canals, plan endodontic treatment, diagnose periapical lesions caused by pulpitis or other factors, and detect perforations and vertical fractures of the teeth.

CBCT imaging makes it possible to reveal the morphology of molar teeth and their internal structures, i.e. the number of root canals, their shape and size. Ioannidis et al. analyzed a case in which CBCT revealed a very rare anatomical disorder concerning the number of roots of molar teeth. Apart from the first right lower molar tooth, all 1st and 2nd molar teeth had only one root and one canal each. On the basis of CBCT scans, La et al. [8] were able to describe an abnormal root canal system of the first lower molar. The tooth had one independent mesial canal which had not been recognized on standard 2D radiograms. Furthermore, Kottoor et al. [18–21] analyzed CBCT scans and described various cases which demonstrate the variability of the root canal system of molar teeth: second maxillary molar with five roots and five canals, first maxillary molar with seven canals in three roots first upper molar with eight canals in three roots, and first upper molar with four roots and a C-shaped root canal in the palatal root [14–16]. C-shaped root canals are a challenge for dental professionals due to the difficulty in their chemo-mechanical preparation and obturation. These problems arise mainly because it is unclear whether the C-shaped opening in the bottom of the tooth chamber extends to the apical part of the root or not. In these cases CBCT provides better opportunities for correct diagnosis of the complicated root canal system which is of great importance, especially in populations in which C-shaped canals occur more often, i.e. Asian ethnic groups [22–27].

The knowledge of morphology, size and shape of root canals enables endodontists to plan the treatment more carefully and choose the right techniques and equipment, especially in curved

canals. The curvature of the canal can be determined by measuring the angle or the radius of the curvature [30]. CBCT imaging provides better opportunities for determining the curvature of the root than conventional periapical radiograms or panoramic radiograms. Estrela et al. [31] suggested that the shape of root canals on CBCT scans might be determined by measuring the radius of the curvature. Moreover, they believe that the curvature may be classified according to the length of the radius, i.e. the distance between the middle points of 6-millimeter-segments on two lines which lie along the apical and the middle part of the root. The longer this distance is, the smaller the curvature of the root is. Radius values bigger than 8 mm imply a slight curvature, whereas values lower than 4 mm imply a big curvature. If the radius is 4–8 mm long, the curvature can be described as moderate. Oliveira et al. [55] used CBCT to perform a comparative analysis regarding transportation and centralization in the apical third of curved roots before and after biomechanical preparation of the canals with rotary files. These systems included 2 reciprocal systems with flexible SS files (K-flexofiles®) and NiTi (SybronEndo®, Glendora, CA, USA) or RaCe® instruments (FKG, Les Chaux-de-Fonds, Switzerland). The results show that CBCT is repetitive, makes it possible to scan several images and provides the most information about the root canal. This enabled the transportation and centralization to be evaluated using the method of counting voxels (volume + pixel = voxel) – isotropic volume units. Cheng et al. [53] discovered that in 30% of the 109 endodontically treated first and second molar teeth CBCT made it possible to confirm the fact that canals whose obturation had previously been evaluated positively on the basis of conventional radiograms were actually not obturated correctly. The highest percentage (42.9%) of discordance was observed for the mesiobuccal canal. The comparison of the inconsistent cases revealed that in 13.8% of the cases canals had not been fully obturated, and in 16.5% of the cases the material had been extruded into the periapical periodontium. Retrospective studies on 509 obturated canals in 300 teeth [54] state that 2D radiograms disclose the obturation up to 1–2 mm from the apex in 88%, 89.3% and 95% for anterior, premolar and molar teeth respectively, whereas when CBCT is used, it occurs less frequently, i.e. in 70%, 73.7% and 79% respectively. Moreover, CBCT enables the disclosure of the extrusion of gutta-percha out of the root canal system. Gambarini et al. [60] provided an explanation of the paresthesia of the inferior alveolar nerve after root canal treatment of the teeth 36 and 37 using CBCT. 3D imaging dis-

closed that gutta-percha had been extruded to the mandibular canal (tooth 37) and the mental foramen (tooth 34) which resulted in paresthesia of the area innervated by the nerves.

CBCT enables dental practitioners to diagnose periapical lesions, both of endodontic and non-endodontic origin with much higher sensitivity [31]. Eliminating the phenomenon of the image overlapping makes it easier to detect and diagnose periapical lesions. Patel et al. [10] scanned 10 first molars in 6 previously prepared mandibles using CBCT. This technique revealed periapical lesions in all cases, whereas when conventional radiography was used, the lesions were visible in only 24.8% of the cases. Therefore, the authors stated that the sensitivity of CBCT is essentially higher, irrespective of the size of the lesion. Tanomaru-Filo et al. [33] described a case of a patient who had undergone endodontic treatment 8 years earlier and developed swelling in the area of the treated tooth. In this case, conventional radiograms did not show any kind of a lesion, and were contradictory to the clinical image. CBCT scans disclosed a serious lesion between the mesial and distal root. The lesions reached the apices and resulted from a perforation of the mesial root. Low et al. [34] showed that 34% out of 109 periapical lesions connected with resection of the apices were visible in CBCT scans and not in conventional radiograms. Christensen et al. [35] obtained similar results after they had studied 58 teeth after extraction. CBCT performed one year after the procedure disclosed 28% more periapical lesions than 2D radiograms. Moreover, authors stated that one week after the apices had been resected, the size of the lesions visible on conventional radiograms was 10% smaller than of those visible on CBCT scans. Liang et al. [36] did research into periapical lesions originating from 143 roots in 115 teeth two years after the patients had undergone root canal treatment. The comparative analysis of 2D radiograms and CBCT showed that CBCT imaging revealed lesions in the periapical region in 25.9% of the cases, whereas 2D imaging techniques disclosed lesions in only 12.6% of the cases.

CBCT imaging is also helpful in diagnosing odontogenous sinusitis [57] and in differentiating between periapical periodontitis and cysts of incisive canal [59]. Nair et al. [56] reported three cases of sinusitis resulting from an inflammatory process which developed due to unsuccessful endodontic treatment and which could not be visualised using conventional radiograms. The authors decided to implement CBCT imaging of the structures of both teeth and sinuses which proved helpful in the diagnosis of the inflammation of the sinuses.

Lesions of non-endodontic origin in the periapical periodontium which seem difficult to diagnose are located in the area of incisive teeth. Incisors are situated closely to incisive canal which can be the place from which inflammatory processes may spread to the roots of anterior teeth. Conventional radiograms are not accurate and sensitive enough to be a basis for diagnosis. One can find four cases in literature in which lesions destructing the bony structures of the palate, i.e. suggesting cysts of the incisive canal, were additionally diagnosed using CBCT. The results of the examination done by pathologists confirmed the diagnosis in two cases, whereas in two other cases the lesions turned out to be a granuloma and a periodontal cyst. Even though CBCT may provide valuable information, histopathologic examination is the most precise method of confirming the diagnosis [59].

Iatrogenic perforations which often lead to root resorption might be also diagnosed more efficiently using CBCT [37–40]. Research by de Alencar et al. [42] proves that canals were perforated in six cases out of 120 cases which constitute 5%, on the basis of CBCT scans. Silva et al. [40] noted a similar frequency of the occurrence of such iatrogenic complications – 4.5% after analyzing CBCT scans of 200 endodontically treated teeth. Literature provides even more examples of perforations being visible only in CBCT scans [33, 37, 39]. Four cases of perforations of the roots in teeth 21, 13, 24, 27 in four different patients with root inlays were invisible in conventional radiograms. It was the “map-reading” strategy, i.e. analyzing each CBCT 0.2/0.2 mm slice along the axis of the root by Bueno et al. [38] that enabled the authors to diagnose the perforations next to metal root inlays. Shemesh et al. [39] also proved on the basis of 45 extracted teeth that intraoral radiographs are of limited usefulness when diagnosing perforations. Furthermore, the authors stated that perforations located in the area

of bifurcation, i.e. “strip perforations”, are the most difficult to diagnose, both using 2D and 3D imaging. In 2D images such perforations are not visible due to the concavity of the root in this region, and in 3D images this problem results from the fact that obturating material, i.e. gutta-percha, does not penetrate the perforation. Hassan et al. [43] state that CBCT is a diagnostic tool well-suited for diagnosing vertical fractures of the teeth. The same authors compared different systems of digital radiography in respect of detection of the vertical fractures and the results show that the best method for diagnosing such fractures is the use of transverse slicing in the I-CAT system. Fractures of molar teeth are found more often than fractures of premolar teeth [44]. Nevertheless, none of the sources state that CBCT is more efficient at disclosing horizontal and longitudinal fractures of permanent teeth [48–51]. It can be explained by the fact that in conventional radiography one can differentiate between 15–20 lines in 1 mm, and in CBCT scans – only between 2 lines, which is a result of much shorter time of exposition [52]. The most recent studies, including in vitro studies, show that CBCT is more precise in diagnosing vertical fractures of the teeth, no matter whether they had undergone endodontic treatment or not.

As has been shown, the use of CBCT in difficult endodontic cases seems to be justified, as it enhances diagnostic possibilities in various areas. These areas of interest include diagnostics of anatomical pathologies, evaluation of obturation, diagnostics of iatrogenic perforations and root fractures, diagnostics of periapical lesions, estimation of the localization of external and internal root resorption and dento-alveolar trauma. This enables the practitioner to understand the complex anatomy of teeth more fully, which results in better performance in endodontic treatment, i.e. better preparation, shaping and obturation of the root canal system.

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