A comparison study between cone-beam computed tomography (CBCT) and regular radiography in endodontics

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Due to the short-comings of current dental imaging methods, represented by conventional radiographs, the researchers were looking for more efficient ways for dental evaluation. The Cone-beam computed tomography (CBCT) is now considered to be a next major achievement in dental imaging, with a wide range of indications at a lower cost and radiation dose compared to conventional computed tomography. The aim of our study is to evaluate the importance of CBCT scans in the assessment of endodontic pathology by comparison with the conventional radiography. The examinations were carried out on 27 patients with 35 root filled teeth in which the quality of the root filling, missed canals or persistence of apical periodontitis were recorded. The results showed a higher percentage of healed periapical lesions when the evaluation was carried out by conventional radiographic examination compared to CBCT ($p < 0.05$). CBCT proved extremely efficient in endodontic therapy regarding the identification of anatomic variations and number of lesions per root canal ($p < 0.05$). CBCT examinations must be taken into consideration for cases in which the benefits of this investigation overcome the risks, offering additional information compared to conventional radiographic examination.

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1. Introduction

The contemporary endodontic practice is characterized by abundant information regarding scientific discoveries, new technology in instrumentation, magnification and imaging methods, which are a real challenge for dental faculties. This is even more important in postgraduate programs, as young specialists must be able to offer the best quality treatments based on up-to-date knowledge and expertise. The radiographic imaging techniques used in dental practice are essential to diagnosis, treatment planning and control follow-up, but the superimposition of teeth and osseous surrounding structures make the interpretation of a two-dimensional (2-D) image offered by the conventional radiographic examination (CRE) very difficult. These problems can be overcome by using a new imaging technique called cone-beam computed tomography (CBCT) which offers, at lower cost and radiation dose, accurate three-dimensional (3-D) images of the teeth and their surrounding structures [1, 2, 3].

By the beginning of the 21st century it became clear that CBCT imaging technique may represent a next major achievement in dental imaging, at a lower cost compared to conventional CT, a radiation dose similar to current used methods as panoramic and full-mouth radiographic examination [4]. This new system is more practical and smaller in size, offering the possibility to collect images of the craniofacial region with high resolution. The most clinically useful aspect of this technique is the complicated software that collects a great volume of data, which then can be broken down, processed or reconstructed. In this way the interpretation process is very easy, given that the doctor has the required knowledge and technical skills [5, 6].

The aim of this study was to compare the efficacy of CBCT in clinical diagnosis and follow-up evaluation of teeth with chronic periapical lesions during endodontic therapy performed by specialists in Endodontics, as the CBCT method is used more frequently in dental implantology than in endodontic treatement. The 3-D images were compared to 2-D views obtained by CRE in order to evaluate the importance of CBCT scans in the assessment of endodontic pathology.

2. Material and methods

The CBCT examination was used for 27 patients with 35 root filled teeth with persistent symptoms, periapical radiolucency or referred or endodontic retreatment. Inclusion criteria: the presence of 2 imaging investigation (conventional radiographs and CBCT) carried out in a one month interval, persistent clinical symptoms without signs of periapical lesion, referred patients for endodontic retreatments. The parameters recorded on CBCT were: the density of root canal filling (score 0 - well condensed and adapted root filling, score 1- gaps < 0.5 mm^2 between root filling and dentin walls, score 2 - gaps of 1-2 mm^2, score 3 – gaps >2mm^2), the length of root canal filling (correct - 0.5-1 mm from the apex or incorrect – overfilling or a space of more than 2 mm from the apex) and the presence or absence of periapical lesion. We also recorded the number of root canals in each tooth, the number of lesions/tooth, the total number of teeth with lesions. All patients were informed about the risks and benefits of this investigation and they consented to participate to the study. It was approved by The Ethical Committee of Scientific Research from the University of Medicine and Pharmacy Târgu Mures and The Council of Medicine Faculty of Lucian Blaga University of Sibiu.

We used 2 imaging systems: X-Ray Soredex (Minray, Soredex Palodex Group Finland and for the CBCT scans - i-CAT scanner (Imaging Science International Inc. Hatfield, PA, 120kVp, 3-8 mA, 0,2 mm voxel resolution 6x16 cm field of view, 26,9 s acquisition time).

The quality of endodontic root fillings was analyzed by UTHSCSA software (UTHSCSA Image Tool for Windows version 3.0, San Antonio, TX, USA).

The recorded data were statistically analyzed using the SPSS version 19.0 (SPSS, Inc, Chicago, IL, USA) and the clinical data were expressed as mean and standard deviation. A chi-square test was used to compare the accuracy of CRE and CBCT in the diagnosis of periapical lesions. For comparison of two independent groups of variables we used Student t-test and nonparametric Mann-Whitney test. The level of significance was set at a p value of 0.05.

3. Results

In most of the cases, dental CBCT images offered complete diagnostic compared to conventional 2-D radiographic examination, although the last exposes the patient to more radiation. The results obtained after comparative examination of the selected cases are presented in Table 1.

There was a significant difference between the number of cases with periapical lesions identified by CBCT (51.85%) compared to conventional radiography (25.92%), with $p < 0.05$ ($p = 0.03$). In molar teeth CBCT scans found a significantly more periapical lesions compared to CRE ($p<0.05$) and the same tendency was measured for the whole group of teeth – mean 0.48 (0.6) for CRE compared to 0.82 (0.52) for the CBCT scans ($p = 0.03$). There were significant differences between the two methods regarding the identification of the number of lesions in each tooth 0.61 (0.82) for CRE to 1.4 (1.48) in CBCT scans ($p = 0.03$). (Table 1). By both methods the mean number of lesions per canal in anterior teeth was higher compared with premolars and molars and in the case of CBCT scans more lesions were identified in molars compared to other groups ($p=0.014$).

Table 1. Comparative examination performed by 2-D conventional radiographs and CBCT.

Clinical parameter	2-D images Mean (SD)	CBCT scan Mean (SD)	p value
Number of roots with periapical lesions	0.42 (0.5)*	0.71 (0.46)*	p = .03
Number of root canals identified in molars	3,12 (0.41)*	3.82 (0.49)*	p = .04
Number of teeth with lesions	0.48 (0.6)*	0.82 (0.52)*	p = 0.03
Number of lesions / canal	0.31 (0.46)*	0.59 (0.5)*	p = 0.005
Number of lesions / tooth	0.61(0.82)*	1.4 (1.48)*	p = 0.03

*Statistical significant differences between variables.

The level of apical root fillings is more difficult to measure on conventional radiographs as dental structures are difficult to separate on 2-D images (Fig. 1).

Fig.1. Upper left first molar examined by conventional 2-D radiograph showing limited information regarding the length of the root filling in all three roots.

Fig.2. Upper left first molar examined by CBCT longitudinal scan could identify the overfilling of 4.1 mm on the palatal root, along with specific measurements of alveolar bone.

On CBCT scans the overfilling of 4.1 mm becomes evident and is accurately measured (Fig. 2). The measurements upon the density of root filling and the presence of gaps between the endodontic material and dentin walls did not show statistical significant differences between the examination methods, however the CBCT reveals more adequate and preciss informations (fig. 3).

Fig. 3. CBCT can be successfully used for the technical evaluation of root filling. It reveals the homogenity and correct condensation technique, without gaps between dentin walls and endodontic material.

In prostetic is necessarely an evaluation of the abutments, and radiographic evaluation is bligatory when endodontic treatement is made. In fig. 4 there is presented the evaluation for the first mandibular premolar with a regular 2-D radiography..

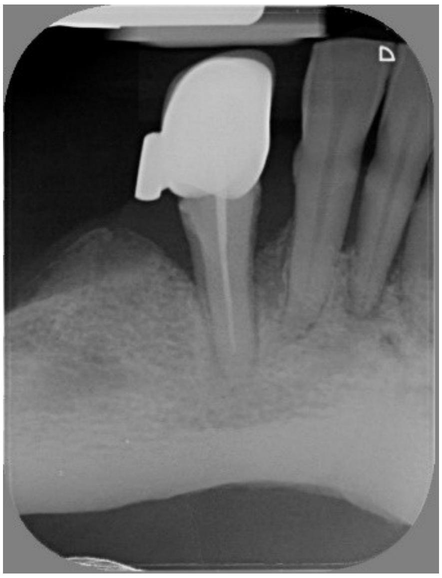

Fig.4. 2-D imaging technique for mandibular first premolar evaluated as abutment in which we could not identify a periapical lesion.

The evaluation indicates a good prognostic in using this teeth as an abutment, but in fig. 5 it apears the evidence of a periapical lesion wich compromites the teeth's prognostic as abutment

Fig. 5. Mandibular first premolar evaluated as abutment in which the 2-D imaging technique could not identify a periapical lesion, as it was placed on the oral aspect of the root. It became evident only on CBCT scan.

Other clinical situations on wich the CBCT scan offers more informations are the endocanalicular retreatement. For example the retreatement of an central incisal teeth by CRE method to identify the root canal conduced to creation of a false canal as shown in fig. 6 with CBCT exam. After the treatement on CBCT confirmed a a proper root filling (fig. 7).

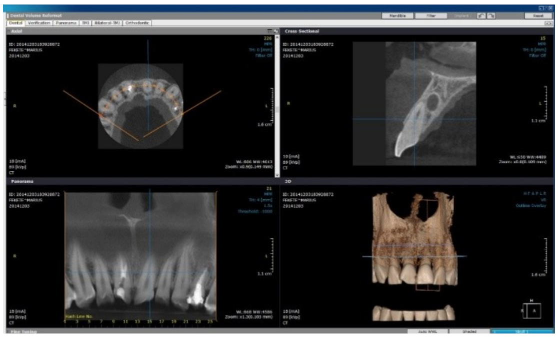

Fig. 6. Central maxillary incisor referred for endodontic treatment due to an obliterated canal, evident only in the apical third of the root. An attempt was made to identify the root canal based on CRE and dental operating microscope but it proved to be impossible and the consequence was the creation of a false canal.

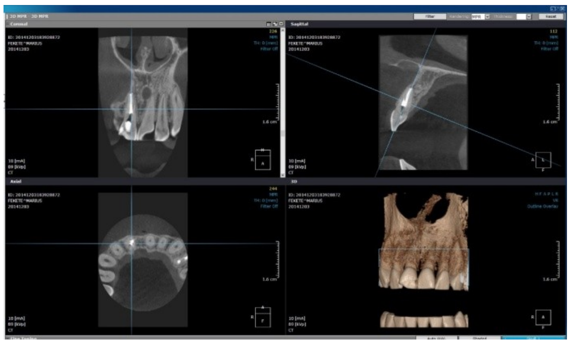

Fig. 7. The case was reevaluated, the true canal was identified and the control CBCT scan confirmed the proper root filling.

The mean values and standard deviation measured for the gaps identified along the root canal fillings in molars, premolars and anterior teeth are presented in Table 2.

Table 2. Mean values, standard deviations and p values for gap measurements recorded in molar, premolar and anterior teeth.

Examination method	Molars	Premolars	Anterior teeth
CRE	0.89 +/- 0.94	1.14 +/- 1.20	1.40 +/- 1.32
CBCT	1.25 +/- 1.02	1.59 +/- 1.28	1.54 +/- 1.48
P values	P = 0.04*	P = 0.03*	p = 0.06

*Statistical significant differences between variables.

There was a statistically significant difference between the measurement of the defects along the root filling recorded in molars and premolars ($p<0.05$) but we could find no difference when anterior teeth were evaluated. This could be explained by the technical difficulties related to endodontic treatment of posterior teeth.

We could identify the voids on both 2-D radiographs and CBCT scans (Fig. 8). CBCT was superior to conventional 2-D radiographic examination regarding the number of root canals identified in a single root, with a statistically significant difference in molar teeth (Fig. 9).

Fig. 8. Lower left first molar referred for endodontic retreatment in which the 2-D radiograph revealed short endodontic filling and apical periodontitis on the mesial root and uncertain diagnosis for the distal one.

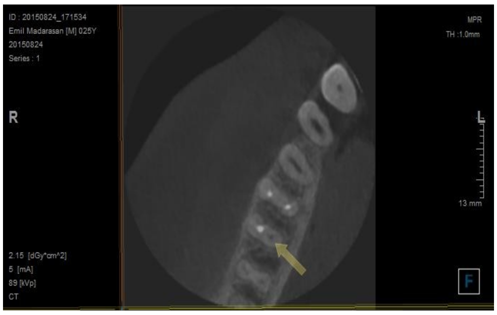

Fig. 9. Lower left first molar referred for endodontic retreatment in which the CBCT scan a second canal could be identified in the distal root.

4. Discussion

The success rate of root canal treatment is considered to be a public health problem and therefore, the establishment of treatment objectives and improvement of techniques are important factors in future higher success rates. We must recognized that for an accurate evaluation of apical bone defects we need a reliable method and the observations of our study are in accordance to other reported data suggesting that an increased number of periapical lesions are being detected by CBCT.

The medical devices must have as main purpose to offer maximum efficiency for the patient without endangering life or health [7]

Successful endodontic treatment is based on the complete identification of the internal tooth anatomy and quite often the conventional radiographic techniques fail to show the entire endodontic system. This becomes more important in obliterated root canal where the proper endodontic treatment is impaired without full access to the apex (Meena et al [8], Abella et al [9]).

The detection of chronic periapical lesions at an early stage is extremely important for the decision upon the best treatment option. In many cases the CRE offers a lower number of periapical lesions compared to CBCT scans, which is in accordance to the observations of our study. As a proof of the importance of CBCT for the identification of chronic periapical lesions, a periapical index was proposed recently (CBCTPAI); it measures the largest lesion on mesio-distal, bucco-palatal or axial direction and gives a score from 0-5.

Abella et al [9] reported a study in which the efficacy of six imaging methods (CBCT, modified canal staining and clearing, spiral CT, peripheral quantitative CT, contrast medium-enhanced radiography and digital radiography) were compared in the ability to identify the complete root canal system of 95 teeth. The best results were obtained with the CBCT and therefore the authors considered it as the gold standard. Despite all this important advantages for dental specialists, according to Patel et al [10, 11] the CBCT imaging system should be used only for difficult cases in which the root canal anatomy cannot be completely evaluated by conventional radiography and dental operating microscope.

CBCT is obtained by using a rotary gantry to which an X-ray source is fixed. A divergent pyramidal or cone-shaped source of ionizing radiation is directed through the middle of the examined area onto an X-ray detector placed on the opposite site of the patient. The X-ray source and detector rotate around the examined area taking hundreds of images in a movement of at least 180^0. Tis is sufficient to provide accurate 3-D images. Even so, CBCT must be considered as a complementary examination rather than a replacement for 2-D radiographs and we indicated this investigation only in difficult cases, in which the initial diagnosis was not clarified by other methods or at control or follow-up appointments of cases with uncertain healing [12, 13, 14].

CBCT proved to be extremely efficient for identification of endodontic anatomy and visualization of missed root canals, in the evaluation of chronic periapical lesions and differential diagnosis between granulomas and cysts, which otherwise can be accomplished only by histological examination. It demonstrated certain superiority compared to 2-D radiographs. Conventional radiographs fail to identify the number of canals and missed anatomy can negatively influence the outcome of endodontic treatment.

Matherne et al [15] demonstrated the superiority of CBCT over CRE in identifying the supplemental root canals and Liang et al [16] reported a success rate of 87% when the 2 years follow-up evaluation was based on CRE compared to 74% when CBCT was used. This is in accordance to our results, as we found significant more root canals in molars when CBCT scans we used and it identified periapical lesions in 51.85% of the cases compared to 25.92% by CRE. CBCT has the ability to detect apical bone resorption in teeth with chronic apical periodontitis before it becomes evident on conventional radiographs. Therefore, for an accurate assessment of endodontic treatments we should compare pre- and post-operative CBCT scans.

Limitations of CBCT:

- it is not able to offer light contrast resolution and cannot be used for soft tissues as it is indicated just for examination of hard tissues.
- Compared to 2-D radiographs is more expensive
- employs a higher radiation dose but with a lower resolution.
- An important limitation is represented by the presence of metal artifacts, produced by metal or amalgam restoration and to a lesser extend by root canal filling materials and implants [17].

Patel et al [1, 10, 11] found that CBCT is superior to periapical radiography for the detection and evaluation of periapical lesions, which can be discovered sooner, in true size, extend and nature. This is also true for root canal anatomy and alveolar bone topography. We agree to the recommendation made by Weissman et al [18] in a recent study that the CBCT imaging technique is to be taken into consideration for those patients with persistent clinical symptoms and without a complete diagnosis based on the clinical and conventional radiographic examination. Alongside to magnification provided by operating microscope, the CBCT will probably soon be considered the golden standard for treatment outcome evaluation for teeth with apical periodontitis.

5. Conclusions

CBCT proved extremely efficient in endodontic therapy regarding the identification of anatomic variations of root canals and follow-up controls. It was more accurate compared to conventional radiography and the differences were more evident in molar teeth.

CBCT must be carried out only after a thorough history and clinical examination were completed. CBCT examinations must be taken into consideration for cases in which the benefits of this investigation overcome the risks, offering additional information compared to conventional radiographic examination.

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Refferences

[1] S. Patel, Int Endod J, **42** (6), 463 (2009).
[2] C, Durack, S. Patel, Braz Dent J, **23**(3), 179 (2012).
[3] P. Badica, I. Tiseanu, G. Aldica, T. Crăciunescu, V. Sandu, G. Jakab, M. Rindfleisch, J.Optoelectron. Adv. M., **17**(11-12), 1636 (2015).
[4] D.A. Tyndall, S. Rathore, Dent Clin N Am., **52,** 825 (2008).
[5] P. Agrawal, S. Sanikop, S. Patil, New developments in tools for periodontal diagnosis. Int Dent J. 2012, 62 (2): 57-64.
[6] V. Shekhar, K. Shashikala, Case Report in Dentistry, 2013, Article ID 564392,
[7] M. Râpă, P. Stoica, E. Tănase, E. Grosu, G. Vlad, J. Optoelctron. Adv. M. **15(**7-8), 807 (2013).
[8] N. Meena, R.D. Kowsky, Dentistry, **4**, 242 (2014).
[9] F. Abella, K. Morales, I. Garrido, J. Pascual, F. Duran-Sindreu, M. Roig, Giornale Italiano di Endodonzia, **29**(2), 38 (2015).
[10] S. Patel, C. Durack, F. Abella, M. Roig, H. Shemesh, P. Lambrechts, Int Endod J, **47,** 502 (2014).
[11] S. Patel, C. Durack, F. Abella, H. Shemesh, M. Roig, K. Lemberg, Int Endod J, **48**, 3 (2015).
[12] B. Acar, K. Kamburoglu, World J Radiol., **28** 6(5), 139 (2014).
[13] T. Eshraghi, N. McAllister, B. McAllister, J Evid Based Dent Pract., **12,** 36 (2012).
[14] K. deFaria Vasconcelos, K.M. Evangelista, C.D. Rodrigues, C. Estrela, T.O. deSousa, M.A. Silva, Dentomaxillofac Radiol. **41**, 64 (2012).
[15] R.P. Matherne, C. Angelopoulos, J.K. Kulilid, D. Tira, J Endod, **34,** 87 (2008).
[16] Y-H Liang, G. Li, P.R. Wesselink, M-K. Wu, J Endod, **37**, 326 (2011).
[17] M.T. Weber, M. Stratz, J. Fleiner, D. Schulze, C. Hannig, Swiss Dental Journal , SSO **125**(3), 293 (2015).
[18] J. Weissman, J.D. Johnson, M. Anderson, L. Hollender, T. Huston, A. Paranipe, S. Patel, N. Cohenca, J Endod., **41** (11), (2015).

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