International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Cone Beam Computed Tomography in the Diagnosis of Chronic Apical Periodontitis and Clinical Decisions: A Review

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Abstract: ***A major paraclinical diagnostic method for the early and late follow-up of the healing process in chronic periapical lesions is the two-dimensional radiographic technique. About 32% of the periapical lesions are detected during a routine radiographic examination of neighboring teeth. Most of the periapical lesions are classified as granulomas, cysts and abscesses. The radiographic images of these lesions are identical and therefore, cannot support an accurate diagnosis, despite the existing clear border between the lesion and the healthy bone, which could be a sign of a cystic lesion. Recent trends in minimally invasive conservative treatment of teeth with inexact endodontic treatment or periapical lesions eliminate this invasive diagnostic method and replace it with the non-invasive reconstructive cone beam computed tomography (CBCT).***

Keywords: CBCT, chronic apical periodontitis, diagnostic imaging method, non- invasive diagnostic method, paraclinical diagnostic method

1. Introduction

In the historical development of dentistry, clinical methods for the diagnosis of chronic apical periodontitis (CAP) have not changed much due to the nature of the pathological process that remains hidden for the clinician and in most cases is asymptomatic.

Although the gold standard for diagnosing the condition of periapical tissues – a granulomatous or a cystic lesion, is the histological examination, this method cannot be used in routine practice for ethical reasons. Brynolf (1967) has established the reliability of the non-invasive radiographic method, compared with invasive histology, in 93% of the cases. Relevance has been established in 98% of the non-inflamed cases and in 81-88% of the inflamed cases. Histological and immunohistochemical studies were the basis for the extensive *in vitro* analysis of periapical tissues.

2. Aim

The aim of this article is to present some of the applications of CBCT in the treatment of CAP.

3. Discussion and Review of the Literature

The clinical, radiographic, and histological diagnosis of periapical lesions have always been a challenge. The incidence of cystic lesions varies from 6 to 55% in some of the studies [17], but is only 15% under the strict histological criteria used by Nair, 9% of these were attributed to true and 6% - to root-canal related cystic lesions [21].

Unlike clinical, paraclinical methods have evolved in association with the rapid technological progress. The advancement of 3-dimensional technology in medical practice increases the accuracy of diagnosis. In the case of suspected CAP, the diagnostic imaging is preceded by Pulp Test Vitality. The method is non-invasive and directs the clinician to the next paraclinical diagnostic method. Depending on the patient's medical history, Pulp Test Vitality can be one of the methods-of-choice for monitoring the results and preventing tooth devitalization, despite the existing periapical pathology [18].

A major paraclinical diagnostic method for the early and late follow-up of the healing process in chronic periapical lesions is the two-dimensional radiographic technique. About 32% of the periapical lesions are detected during a routine radiographic examination of neighboring teeth. Most of the periapical lesions are classified as granulomas, cysts and abscesses.

The radiographic images of these lesions are identical and therefore, cannot support an accurate diagnosis, despite the existing clear border between the lesion and the healthy bone, which could be a sign of a cystic lesion. Today, it is assumed that a clearly outlined lesion is a radiographic sign of a long-year lesion that grows slowly, and the diffused border is an indication of a rapidly progressing osteolytic process. The final diagnosis of periapical lesion can be made only histologically. Since this is an invasive method, in recent years, a non-invasive diagnostic method or a method of minimal error rate has been successfully introduced [5, 7]. The preliminary diagnosis can be made on the basis of some of the following characteristics:

- The periapical lesion involves one or more teeth with non-vital pulp tissue;

- The lesion is approximately greater than 200 mm^2;
- The lesion, as an area of osteolysis, is well-outlined with a compact osteocsclerotic shaft on the radiograph;
- The lesion produces typical straw yellow exudate upon aspiration or drainage [12].

One of the controversial questions in Endodontics is "do cysts heal with nonsurgical treatment?"[25]. In current clinical practice, precise methods, e.g. CBCT or methods without beam loading, such as Ultrasound or Doppler sonography have been also introduced [28]. Precise diagnosis is important when choosing a treatment protocol. The limitations of OPT in detecting the precise location and presence of a chronic periapical lesion or a resorptive process are related to the lack of a detailed image of the structures in this area, for both the conventional and digital method. Intraoral periapical radiographs, based on the bisecting angle technique, are the most widely used diagnostic imaging method. The limitations of this method are due to the way of positioning the film-object of study-tube, which reproduces images with deformations and superimposing bone structures, thus making the clear diagnosis impossible. Upon examination of multirooted teeth, the probability of diagnosing periapical lesions is reduced, due to superimposing of similar structures [8].

Even Dylewski (1971) discussed the importance of early detection of changes in bone structures and the choice of a treatment protocol, as well as the prediction and monitoring of late results in the 3rd and 6th month, 1st and 4th year [10]. The comparative analysis of periodically conducted imaging examinations of periapical lesions is the method for assessing the occurred healing processes or progression in the apical zone. The used diagnostic imaging methods were conventional (plaque) and digital - based on the bisecting angle technique, parallel intraoral technique and parallel intraoral technique with an ortho-positioned holder. After the presentation of the method of digital radiography in the early 80's of the last century, it became a subject of both clinical and research interest. In both main diagnostic methods, there were errors of technical nature and errors associated with the clinician's subjective assessment of the radiologic findings [4].

The first problem that complicates the assessment of the periapical area in conventional radiographs is the different transparency, contrast and positioning of the beams, the object and the film [4]. Superimposing of adjacent anatomical structures is also a factor that hinders diagnosis and assessment of apical bone structures [3, 5]. The limitations of radiologic examination are associated with the early diagnosis of initial bone changes. The structural noise, which depends on the complexity of the object on the radiograph, is one of the limitations for obtaining a detailed image of the bone structures [1, 9, 15]. The reduction in structure-borne noise can be achieved by subtraction digital radiography, which eliminates the regions with identical images [1, 23].

The measurements of distances of the axial and sagittal size, made on the two-dimensional radiograph, are of relative accuracy for the different combinations of positions of the radiographic elements: direction of the beams, positioner (or the absence of such positioner), object of the study and receiver of the image (the radiographic film or sensor). Because of the peculiarities in the formation of radiographic images, the orientation of the beam relative to the object (tooth) is of great diagnostic importance.

A scientific consensus has been achieved that an accurate and correct diagnosis can be made only through an invasive technique - histological analysis of periapical tissues [16].

Recent trends in minimally invasive conservative treatment of teeth with inexact endodontic treatment and periapical lesions eliminate this invasive diagnostic method and replace it with the non-invasive reconstructive cone beam computed tomography (CBCT).

Cone beam computed tomography was developed in the late 1990s. This method offers reduced exposure, radiation, and scan time. It was approved by the FDA in 2000 and was put into practice in 2001. Image reconstruction is achieved using computer algorithms ultimately producing 3D images at high resolution. The contemporary CBCT offers an endodontic mode, which is very useful for endodontic practice.

According to some authors CBCT allows diagnosing and differentiating the density of contents - liquid in the cystic cavity or granulation tissue [16, 21, 25, 27]. It was found that the CBCT-scan may be clinically more accurate and more useful than the biopsy [25]. In contrast Rosenberg et al. found poor accuracy for CBCT in differentiating cysts from granulomas [29]. Modern innovations in diagnostic imaging include both digital radiography and cone beam computed tomography. CBCT is a relatively new method for examination, which has a number of advantages over conventional medical CT scans. Magnetic resonance imaging (MRI) is also applied in clinical cases with difficult differential diagnosis. It is widely used in the diagnosis of soft tissue processes [2]. On the first place for the CBCT is the significantly lower radiation exposure of the patient, compared to conventional computed tomography (CT). Undoubtedly, the development of this technique significantly enhances the preoperative diagnosis, and in some cases, the postoperative monitoring of results. The exposure time in CBCT ranges from 5 to 40 seconds [31]. Comparatively short exposure, together with the low intensity radiation, enabled by the digital technology, makes the radiation exposure during the CBCT examination (depending on the equipment) to about 25 times less than conventional CT. Another advantage of CBCT over CT is the isometric voxels amounting to 0.09 mm and ensuring a very high resolution. This leads to more accurately distinguished the boundaries of anatomical objects and correspondingly - high precision of linear measurements.

In the CBCT-examination, both two-dimensional images at arbitrary projections and three-dimensional images can be obtained, which can be rotated and moved in the desired manner by the clinician. Three-dimensional images can be panoramic, i.e. of the whole object positioned in the scanning plane, or of certain parts of it. By using the CBCT, it is possible to measure quickly and accurately the parameters of the available bone and a variety of two-dimensional sections, thereby obtaining a detailed information of early periapical changes which two-dimensional radiographs could not detect (Figure 1,2)[31].

Figure 1: a/Preoperative x-ray on tooth 21;
b/Postoperative x-ray on tooth 21.

The application of the CBCT technology in endodontic practice has tended to become a routine daily practice in modern diagnosis: examination of endodontic pathology and canal morphology, evaluation of lesions of endodontic and non- endodontic origin, diagnosis of root fractures and trauma (Figure 4), detailed examination of the internal and external root resorption (Figure 5), invasive cervical resorption and preoperative planning for orthograde treatment or for endodontic surgery (Figure 6)[6, 13,14].

Figure 2: CBCT of maxilla: the periapical lesion around the root apex of tooth 21 can be clearly seen, while it cannot be diagnosed on the 2-dimensional x-ray.

CBCT technology allows each root and its adjacent structures to be examined and measured by a precisely reconstructed image (Figure 7, 8). This is confirmed in the literature by many scientific research studies [3,4,5,6,7,11,13,20,29].

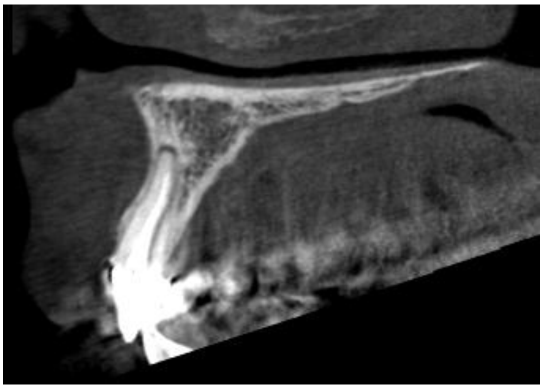

Figure 3: Sagittal CBCT section through tooth 21

Diagnostic information from CBCT examination is essential in influencing clinical decision making. This accurate imaging leads to better treatment planning decisions and potentially more predictable outcomes in endodontic treatment. This high-resolution method can visualize anatomical variants such as accessory mental foramina, mandibular incisive canal and lingual vascular canals [32, 33, 34]. This information can be useful in cases of apical osteotomy, dental implantation and other surgical interventions in treatment of cases with CAP.

Evaluation of a periapical lesion with CBCT change the estimation of size and choice of treatment among endodontists compared to periapical radiography. Choosing the most appropriate treatment approach by using the most accurate imaging modality would ultimately reduce significantly the cost and morbidity in patients undergoing endodontic therapy.

Figure 4: X-ray and CBCT on tooth 11 with fracture

Figure 5: X-ray and CBCT on tooth 25 with external resorption

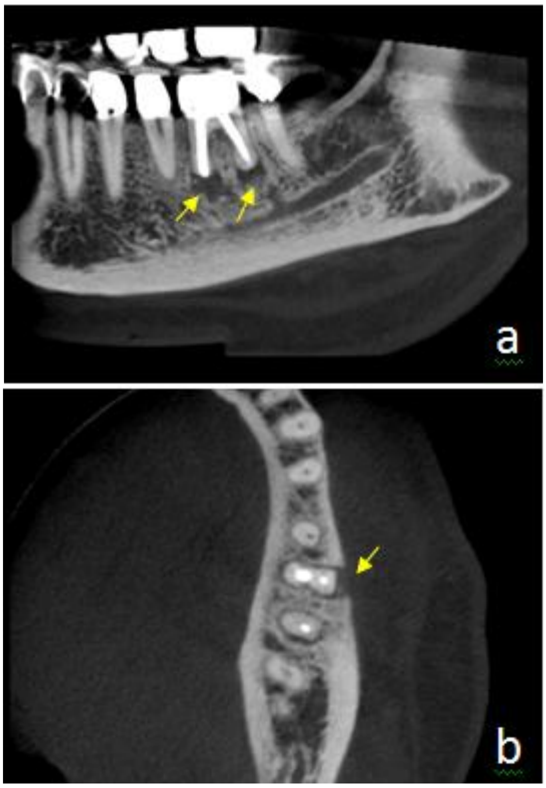

Figure 6: a,b. Sagittal (a) and axial (b) CBCT slice on tooth 36 - preoperative planning for endodontic surgery.

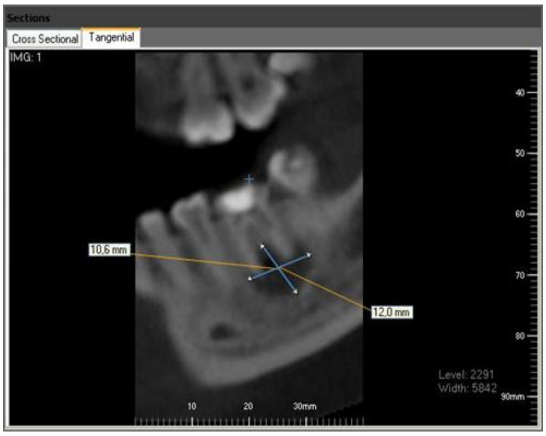

Figure 8: Measurement of the reconstructed image before endodontic treatment - sagittal slice on tooth 36.

Figure 7: Measurement of the reconstructed image before endodontic treatment - coronal slice on tooth 36.

It has been shown that in 70% of the cases, CBCT images provide more details of the structures, compared to periapical radiographs.

Stavropoulos *et al*. [26] have shown that the CBCT has a higher sensitivity, positive predictable value of the examination and it gives a more precise diagnosis than intraoral radiographs in assessing the presence of artificial bone defects. In about 50% of the cases, cone beam technology provides the possibility of diagnosing bone lesions that cannot be detected by intraoral radiographic methods [19, 26]. CBCT could be used to determine the nature of periradicular lesion. Simon *et al*. have exploited the potential of the technique for differentiating liquid-filled from tissue-filled lesions [25]. They found that the CBCT technology and the possibility to adjust the contrast could assist in the differential diagnosis with respect to making more specific diagnosis of periapical lesions of endodontic origin - cyst or granuloma [24].

Considering that every radiographic image examination involves ionizing radiation, including CBCT, this contemporary diagnostic tool must be justified and optimized. There is also a need for robust continuing education in CBCT. There is a guideline of European Society of Endodontology, a position statement, which is designed to aid clinicians who are contemplating using, or are already users of CBCT [22].

4. Conclusion

The preoperative cone-beam computer tomography (CBCT) image provides more diagnostic information than a preoperative periapical radiograph and this information can directly influence a clinician's treatment plan. The problems associated with the diagnosis of periapical lesions and the need for accurate non-invasive diagnosis are a pre-requisite for searching secure enough methods by which to choose the appropriate treatment plan without waiting for an extended period of time, which could lead in some cases, to irreversible changes in the dental supporting apparatus and the need for extraction of the tooth.

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