The Role of the Cone-beam Computed Tomography as an Incremental Tool in Endodontic Diagnoses

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Abstract:
Challenging clinical situations require additional resources for the development of diagnosis, and consequently, improved prognosis. Tooth morphological variations are a constant challenge for diagnosis and successful endodontic therapy. A well-conducted clinical examination is decisive and sovereign in the diagnosis. However, an isolated segment is not base to this process. A set of associated clinical and complementary examinations, among these, the analysis through images are responsible for diagnosis. To obtain essential information in clinical endodinetics, cone-beam computed tomographic (CBCT) imaging can be used in all phases of treatment including diagnosis, treatment planning, during the treatment phase, and through post-treatment assessment and follow-up. CBCT constitutes as an essential modality image provided by the three-dimensional spatial relationships, thus becoming an outstanding resource for complementary diagnostic. In addition to assisting a diagnosis, collaborating in the treatment plan, guiding and monitoring any therapeutic maneuver, analysis through images is recommended when the clinical examination is not sufficient to prepare the appropriate treatment sketch. Currently, the endodontic treatment is one of the specialties in the dental clinic that makes more use of radiology examination, indispensable in any surgical treatment step for providing the basis for endodontic therapy.

Since the discovery of X-rays, radiology witnesses the development of new technologies, in this way, the first techniques intra and extraoral radiographs were established. Until then, the images were based on two-dimensional (2D) representations. Later, the principle of computed tomography (CT) was offered, providing an image of a section or cut off the structure of interest, whereas the structures that are above or below the core layer appear blurred. For this purpose is used, the movement of the film and radiation source to create the desired object cuts. Around age 70 has emerged an important tool for three-dimensional (3D) visualization of anatomical structures and pathological processes the CT. With the development of computing, provided the possibility of manipulating radiographic images using computers, and therefore, it would be required to obtain digital images. This progress has enabled the development of new examination method in diagnosis practice that has revolutionized radiology. The medical CT scan represented one of the greatest scientific revolutions of today, detecting clinically meaningless pathologies in medicine. With specific dental software to the area, that allows, through the reshaping data, perpendicular images to the dental arches, and panoramic views of interest. Although obtain good images and possessed specific software, this technique has not been consolidated in dentistry due to a number of factors. Among them, the lack of specificity, high cost of the device and examination, high dose of radiation, and limited communication between physicians and dentists. In an attempt to overcome such limitations arises the cone-beam CT (CBCT).

Introduction
Diagnosis represents the basis for structuring dental treatment, specifically in clinical cases where the patient’s main complaint is pain. In this context, a well-conducted clinical examination is decisive and sovereign in the process. However, an isolated segment is not base to the diagnosis and a set of associated clinical and complementary examinations, among these, the analysis through images are responsible for this purpose. The imaging has gone through constant technological advances,
examination can also define the morphology and extension of cystic lesions.\textsuperscript{10-12} Besides being able to assess the effectiveness of any technique, even allows observing malpractice and operational conditions that can disrupt or even prevent the return to normality of the apical and periapical structures.\textsuperscript{14,16} Thus, the ability to obtain images in the 3D in dentistry was able to increase the ability to diagnosis and dental planning.\textsuperscript{2,18,10} Considering the above factors, the CBCT is a mark in contemporary dentistry. The aim of this study was to discuss, through literature review, the importance of the use of CBCT in diagnosis and treatment in endodontics.

**Indications of CBCT in Endodontics**

According to Scarfe et al.,\textsuperscript{17} in 2009, periapical radiographs are still the most utilized. However, the usefulness of CBCT cannot be challenged because they help predict potential complications related to endodontic treatment. There are specific, both pre- and post-operative circumstances, that CT constitutes as an essential modality image provided by the 3D spatial relationships, thus facilitating the visualization of anatomical structures, forming proper image geometry, and contrast, plus allow a diagnosis with greater depth of detail.\textsuperscript{4,5,8,11}

Considering that the action of the endodontists is taken in millimeters, it is essential a method to investigate the minutiae of the area being analyzed. Through examination imaging might be analyzed quality parameters, as well as evaluating the aftercare and check the integrity of periapex.\textsuperscript{14} Conventional imaging methods have many limitations of diagnosis such as overlapping, 3D appearance, and image distortion prominently among the main ones. Meanwhile, the CBCT came to revolutionize the diagnosis since all mentioned limitations are overcome.\textsuperscript{15,18,19} The requisition of CBCT, according to the American Association of Endodontics,\textsuperscript{11} in 2011, indicated in cases of dental trauma and fractures, evaluation of anomalies, differential diagnosis of diseases, analysis of root resorption, perforations, planning, and preservation of apical surgery cases.\textsuperscript{20}

The auxiliary imaging methods are essential for the correct diagnosis and treatment of pathological changes as they allow visualization of dental and alveolar tissue morphologies.\textsuperscript{2} Knowledge of external and internal morphology of root canals and possible anatomical alterations has great significance in determining the success of endodontic treatment.\textsuperscript{2,8,17,18} Therefore, the severity of the curvature of the root edge canal can be a challenge to the endodontist, especially in teeth with torn roots, requiring caution in the choice of technique and endodontic instruments best suited.\textsuperscript{21} Estrela et al.,\textsuperscript{21} in 2008, described and discussed a method for obtaining the radius of curvature of the root images from CBCT. In images with high-quality resolution measurement of the radius of curvature can be obtained from the circumerter, determined by two half-straight lines overlaid on the root canal. Knowing the radius of the root curvature allows a more precise planning of intracanal instrumentation and minimizes the impact of anatomical difficulties and limitations of endodontic instruments. The need to evaluate the structures in 3D is noted, especially in complex cases in which conventional radiographs do not reveal exactly important, to obtain the correct diagnosis and treatment planning aspects. However, this method has recently been overcome by CBCT including the treatment of endodontic problems,\textsuperscript{5,22-24} different anatomical morphologies,\textsuperscript{20,21} fractures,\textsuperscript{6,15,22,23} and bone loss in the furcation area and root perforations.\textsuperscript{9,24}

**Periapical Periodontitis**

The CBCT has been used as a valuable resource in the differential diagnosis lesions of endodontic origin. According to Cotti et al.,\textsuperscript{25} in 1999, using CT was possible to assess the true extent of the lesion and its relationship to space with important anatomical areas. CT also allowed specific information on the type of lesion and observation of bone healing occurred after endodontic treatment. Attempts to diagnose pre-operative periapical lesions with periapical radiographs, contrast media, stain Pap and albumin tests, proved inaccurate. Recently, with the advent of CBCT, the density contrast may allow greater accuracy in pre-operative diagnosis.\textsuperscript{26} Simon et al.,\textsuperscript{27} in 2006, compared the CBCT scanner through NewTom 3G and biopsy in the differential diagnosis of periapical lesions (cysts and granulomas). For comparison, 17 scans with pre-operative periapical radiolucency were performed. After the surgery, a biopsy report was obtained and compared to the images. The results showed that in 13 cases (76.47%), the diagnosis between the CBCT scan and the report of biopsy was compatible. In four cases, the CBCT pointed cyst and the histological diagnosis was a granuloma. In these, the reading of the CBCT scan data indicated the diagnosis of cyst and the biopsy report reported apical periodontitis (granuloma). Reviewing the histological study of these four discordant cases, the authors found consistent diagnostic data content and architecture of radicular cyst, but without clear evidence of the contours of the epithelium. The fragmented sections of small lesions allow for loss of epithelium and often do not represent the entire lesion. Given these findings, the authors concluded that the CBCT tends to help in differentiating periapical pathologies, such as cysts and granulomas, without the need for surgical invasion feature.

In order for endodontic retreatment, many factors must be considered such as the extension of existing lesion, anatomy of the root canal, comparison with regional anatomical structures, and among the other factors. This information may result in the decision to endodontic retreatment with possible surgical completion (Figure 1a-d). Routinely, periapical radiographs are used in diagnosis, treatment, and monitoring repair of periapical lesions. However, radiographs showing 3D structures from 2D images presents overlap, causing

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**References**

- Scarfe et al., 2009.
- Estrela et al., 2008.
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limitation due to the fact the study. These limitations become more evident particularly in the region of an upper molar with its complex anatomy. To overcome this limitation, it has been used at least two radiographs of the area with different horizontal angles. On the premise of compare, the diagnostic information and radiation dose between CBCT and two periapical radiographs, Huumonen et al., in 2006, studied 39 cases of upper molars, resulting on a superiority of CBCT diagnostic information regarding periapical radiography. The CBCT provides important information in the decision of endodontic retreatment, but the authors emphasize that failures in the diagnosis of periapical radiographic technique do not justify the routine use of CBCT in endodontic treatment. However, due to the financial and biological cost, indications should be carefully studied.

Lofthag-Hansen et al., in 2007, compared conventional periapical radiography with 3D imaging in the diagnosis of periapical lesions. For this purpose, 46 teeth of 36 patients were analyzed. Upper molars and premolars and lower molars with endodontic problems were examined with periapical radiograph and CBCT (Accuitomo 3DX device), aiming to observe the number of roots and canals, the presence and location of periapical lesions and their relationship with the surrounding structures. Of 46 teeth, both techniques showed lesions in 32 of them and in 10 lesions were diagnosed only in the images of Accuitomo 3DX, although sometimes technical artifacts appear. In 32 of 46 cases, all of the observers agreed on the diagnosis offered with Accuitomo. Erosions or perforations on the buccal and or lingual/palatal were noted more frequently in the images of Accuitomo than in periapical radiographs. The study concludes that the tomographic images reveal additional information not found in periapical radiographs. Such information consists in better visualization of the anatomy of roots and canals, a better understanding of the location of the lesions and the relationship between the lesion and the maxillary sinus, and also a more accurate assessment of lesion sizes.

Estrela et al., in 2008, assessed the prevalence and risk factors of apical periodontitis in endodontically treated teeth in a selected adult population of Brazil. For this study, 1372 periapical radiographs of teeth with endodontic treatment were analyzed, considering the filling quality, status of coronal restoration and the presence of intracanal posts associated with apical periodontitis. The prevalence of apical periodontitis with adequate endodontic treatment was low (16.5%). This number was reduced to 12.1% when considering appropriate filling and coronal restoration. Teeth with adequate endodontic treatment, and poor coronal restoration, showed the prevalence of apical periodontitis equal to 27.9%. Apical periodontitis increased to 71.7% in teeth with inadequate endodontic treatment and improper coronal restoration. When
inadequate endodontic treatment was combined with adequate coronal restorations, it was possible to observe 61.8% of apical periodontitis. The prevalence of apical periodontitis was lower when associated with the high technical quality of endodontic treatment. Inappropriate coronal restoration increased the risk of apical periodontitis even in the presence of adequate endodontic treatment. The presence of intracanal posts did not influence the prevalence of apical periodontitis.

Estrela et al.,30 in 2008, described, by the index periapical, apical periodontitis based on measurements corresponding the periapical radiolucency interpreted in CBCT exams. For this study, 1014 radiographs of 596 patients with a history of endodontically treated teeth were used. Periapical radiographs were taken based on the radiographic technique of parallelism. The CT images were obtained with Accuitomo 3DX. Three observers, using the calibrated PICBCT criteria (Periapical Index of CBCT), performed the evaluation. The apical periodontitis was detected in 39.5% and 60.9% of cases by periapical radiography and CBCT, respectively, concluding that CBCT was more accurate, in comparison with periapical radiography, for diagnosis of apical periodontitis, identifying almost 61% of cases using CBCT.

Estrela et al.,31 in 2008, reported the precision and accuracy of the CBCT images, the panoramic radiograph, and periapical conventional radiography, in the detection of periapical lesions. They examined 888 patients with at least one tooth with a history of endodontic infection, totaling 1508 teeth. Sensitivity, specificity, presumptive values and accuracy of panoramic and periapical radiographs were calculated. The results demonstrated that the prevalence of infection endodontic was significantly higher with the CBCT than to conventional methods and that the presences of these lesions were only correctly identified with conventional radiographs when presented at a more advanced stage. The study concluded that CBCT was important in the identification of periapical lesions and in establishing a differential diagnosis.

According to the evaluation of Balasundaram et al.,32 in 2012, auxiliary diagnostic methods aid in estimating the exact size and nature of the periapical lesion in relation to determine treatment and prognosis. Performed a study considering the ability of endodontists in determining the apical pathologic lesions size of and select the appropriate method of treatment of lesions based on CBCT images. Twenty-four24 individuals were selected, and six observers analyzed the radiographic and tomographic images. In this study, there was no significant difference between examinations with the use of 2D or 3D images for the items considered. The size of the lesion and treatment plan assigned were the same for both as the CBCT to conventional radiography.

Bornstein et al.,33 in 2012, confronted periapical radiography and CBCT in the pre-operative evaluation of lower molars. Used in the study, 38 molars, totaling 75 roots. The homogeneity of the channels, apical extension, as well as the number of root canals was examined by both CBCT and by intraoral radiography. In lower molars, due to better discrimination of anatomy of the root canal, it is recommended inspection of tomography before apical surgery.

**Assessment of Presurgical Lesions**

In planning periradicular surgeries, CBCT has also shown to be efficient. Thus, it is possible to assess the relationship beyond the root apex with anatomical structures, check the distance between the cortical bone and root apex, root morphology in 3D and real odontometry34 (Figures 1e-h). To confirm the accuracy of CBCT scans, Low et al.,35 in 2008, confronted them with periapical radiography for detecting periapical lesions in the upper premolars and molars referred for endodontic surgery. The study showed that of the 109 lesions identified with CBCT, 34% were not diagnosed with conventional radiography. The detection of lesions with only radiography was more difficult in the second molars or near the maxillary sinus floor roots. Additional findings were seen with more frequently CBCT when compared to radiography, including expansion of lesions into the maxillary sinus, sinus membrane thickness and root canals not detected in endodontic treatment.

The CBCT has become more prevalent in the planning of endodontic surgery.33,35,36 The additional information provided by this tool allows proper identification of small lesions not seen on intraoral radiography because there is no need for cortical bone destruction for viewing erosion in cancellous bone.33,35 Thus, provides further differential diagnosis among the possible pathologies and anatomical structures.36 Well-performed clinical history and examination associated with good quality of laboratory tests is essential for pre-operative diagnosis of apical surgery.33 CBCT also allows evaluating the true extent of periapical lesions and their relationship to important anatomical structures.16,23,27 Furthermore, provides specific information about the type of injury and the degree of bone repair occurred in nonsurgical endodontic post-treatment.37 On the premise to evaluate the detection of the dimensions of apical lesions, the relationship of these with the mandibular canal, and the size of the buccal bone.33

**Trauma (Radicular Fractures)**

The alveolar-dental trauma affects increasingly the population, with indexes that vary between 4% to 30% and can cause esthetic, psychological, social, and therapeutic problems.22 Especially in cases where there is no separation of the fragments, the correct diagnosis is essential. Thus, it becomes relevant to the precise clinical examination and a very detailed radiographic examination.15,22 One reason that complicates detection of fractures is the angulation of the central beam of X-rays from conventional radiographs, relative to the fracture plane. On the occurrence of root fractures, radiographic
examination should be thorough, since the prognosis of the case is closely related to the visualization of the fracture line, which for the beams to be observed X-rays has to coincide with the line crack.22,23 Still on the difficulties analysis of vertical root fractures and cracks, refer to the problem of initial diagnosis of teeth with endodontic treatment because the fracture line, which is radiolucent, in many cases coincides with the radiopacity of endodontic materials. This obstacle may be compromising the diagnosis, leading to tooth loss.15,22 In an attempt to provide a better diagnosis of vertical root fractures, some authors mention the use of endodontic micro cameras in which the illumination is carried by optical fiber attached to the camera.22 Recent studies have shown that small amounts of CBCT scan have a high sensitivity and specificity in detecting root fractures.37,38 TC is an aid in the diagnosis of vertical root fractures half, allowing visualization, localization, and determining the extent of the fracture and presented better results when compared with conventional periapical radiographs for the diagnosis of fractures dental root.6,15,22,23,37,38

In this sense, the use of CBCT can be valuable.22 Besides helping in determining the type and severity of injuries is more sensitive in identifying them compared with periapical radiography.3,4 Being evaluated from only one scan without distortion and overlap.7 In this context, Bernardes et al.,22 in 2009, compared the ability of CBCT, with Accuitomo 3DX machine, to diagnose root fractures. Study participants were 20 patients with endodontically treated teeth. After radiography, the examiners noted the pathological characteristics according to specific scores. After the reconstruction was performed, the evaluation of radiographs and CT scans by two observers, a radiologist and an endodontist. According to the results, it was concluded that CBCT was superior to conventional radiography in visualizing root fractures (Figures 1i-k).

Subtle fractures without separation of adjacent segments are sometimes not detectable because of clinical conditions that overlap with the anatomical structures and artifacts that may mimic or hide the lines of fracture.22,37 For this reason, Costa et al.,15 in 2011, in an in vitro study posted the root fragments to their original position after the induction of horizontal fracture. This procedure allowed the emergence of fracture lines similar to that observed in cases of immediate post-trauma, and therefore, difficult to detect. In such cases, the influence of the field of view is important. This selection is directly related to the voxel size and influence on the spatial and contrast resolution. Large volume tomography provides less resolution and contrast, compared to the small volume.

Özer,37 in 2011, compared the diagnostic accuracy of CBCT with different voxel resolutions in the detection of vertical root fracture. Sixty teeth, 30 with root fractures and 30 without fractures, were examined using an i-CAT scanner in 4 different voxel resolutions (0.125, 0.2, 0.3, and 0.4 mm). According to the results, there was no significant difference between the resolutions. Thus, they concluded that CBCT is accurate in detecting root fractures. Hassan et al.,39 in 2010, compared the accuracy of CBCT in the detection of vertical root fractures and if there was an influence on the location of the dental arch. To accomplish this, they examined five different systems that use cone beam technology. For this study, 80 teeth, endodontically prepared, were divided into four groups and placed in dry jaws. The CBCT was taken with five different commercial systems. Two observers evaluated images in axial, coronal, and sagittal reconstruction plans. According to the results, there was a significant difference in the detection accuracy of the five systems. The axial slices were significantly more accurate than sagittal and coronal slices in the detection of vertical root fracture in all systems. Fractures were better identified between molars than premolars.

**Radicular Resorption**

Pathological root resorption may occur associated with various conditions such as trauma, reimplantation, orthodontic treatment, irregular eruption and expansion of tumors, and cysts.22,23,37,38 However, it is most often associated with inflammation of infectious origin and may be internal or external.12,40,41 Both have great relevance in the endodontic practice, so has been the subject of several scientific studies. The external apical root resorption occurs without clinical symptoms, so diagnosis is invariably through images.40,41 Laux et al.,10 in 2000, evaluated the reliability of routine radiographs in the maintenance of apical root resorption, correlating the radiographic diagnosis, and histological features. Specimens were collected with a diagnosis of apical periodontitis with radiographically apical radiolucency. After the extraction, the teeth were processed and histological slices were prepared. When the histological and radiographic data were combined, a total of 104 pairs histologic-radiographic were available for analysis. Of the 104 radiographs, 51% were periapical films and 49% panoramic radiograph. In the first part of the study, radiographs were analyzed by an endodontist without knowledge of the histological diagnosis. The teeth were examined with regard to the absence or presence of apical third radicular resorption. In the second part of the study, histological cuts were analyzed by microscopy. Histologically, two types of radicular resorption were diagnosed: (1) Defects that have been repaired with cement and (2) Gaps not repaired. Only resorption un repaired received histological evaluation. During the third phase, the correlation between the radiographic diagnosis and the histological findings were analyzed. Radicular resorption was radiographically diagnosed in 19% of teeth examined. On histological examination, this change was assessed in 81% of specimens. The evaluation correlating the radiographic diagnosis with histological findings revealed coincidence of 7% of specimens, no correlation was found in 76% of cases.

Several biological and technical factors contribute to a poor determination of radicular resorption on radiographs,
depending on the size and location of the root defect, variation in bone and dental anatomy and lost mineral content.\textsuperscript{41} With regard to technical factors, the authors mention type and number of radiographic used angulations, film sensitivity, and processing radiographic.\textsuperscript{10,41} The diagnosis of radicular resorption might not always be achieved with complete safety by periapical radiographs, even changing the angles of the radiation beam, due to overlap in the 2D image of the periapical radiograph.\textsuperscript{41} In this sense, the authors emphasize the role of CBCT in the diagnosis of root fractures and root resorption, highlighting the power of this exam to diagnose the nature and extent of injury with increased accuracy when compared to multiple radiographs\textsuperscript{34} (Figures 1l and m). Patel et al.,\textsuperscript{41} in 2009, investigated the diagnostic accuracy of periapical radiography with CBCT for detecting internal and external resorption. The strategies for treatment of the resorption lesions using periapical and CBCT of 15 teeth were also analyzed. As a result, it was possible to observe that the periapical accuracy to was lower than the CBCT and, by this reason, it was considered the right choose for resorption detection.

The invasive cervical resorption is a type of external resorption that begins across the epithelial attachment and commonly affects mineralized tissues (dentin and cementum), and except for some stages, the pre-dentin layer protects the pulp tissue, being less mineralized.\textsuperscript{42} Besides trauma, orthodontic treatment, reimplantation, expanding cystic lesions, and feline herpes virus also appear to be an etiologic factor for the development of invasive cervical resorption.\textsuperscript{43} Although the cementum on the surface of the root dentin prevents reabsorption, damage to it, as a result of any of the causes mentioned, can expose the root dentin to osteoclasts thus starting the process of resorption.\textsuperscript{43} Estevez et al.,\textsuperscript{42} in 2010, describe a clinical case with a history of trauma in the upper anterior region, whose main complaint was color change in the upper left central incisor. The diagnosis and extent of the injury are difficult to assess with conventional X-rays, so the CBCT was indicated. Based on CBCT images and 3D reconstructions, diagnosis of invasive cervical resorption Class III was determined presenting resorption defect involving the cervical third of the root. Thus, the CBCT is effective in the detection of lesions and size, as well as in monitoring. Through the CT scan was possible to observe aspects undetectable by conventional diagnostic methods.

**Image Artifacts**

One of the major issues facing due to the use of CBCT is the presence of artifacts.\textsuperscript{1,9,23,44} Thus, should be highlighted the care with metallic structures, so common in the patient’s mouth, as dental amalgam fillings, metallic fixed prosthodontics, and orthodontic appliances.\textsuperscript{1,10,12,44} Furthermore, factors such as field of vision, the slice thickness, and the dosage unit may interfere with the increase or reduction of metal artifacts in CT images.\textsuperscript{9,10,13,17,18} This common phenomenon in CT scans is due to the increased energy of the primary beam from X-rays passing through the object.\textsuperscript{24} The formation of image artifacts can significantly complicate the diagnosis of fractures and resorption, in other words, severe false negatives\textsuperscript{6,12,41} (Figure 1n). Therefore, despite the excellent capability of the method, in these cases, the conventional periapical radiography is indicated as a complementary examination to establish the diagnosis. Proving that the benefits of each system, both radiographs, as the scans should be used.\textsuperscript{8,12}

Metal objects can cause artifacts that reduce the quality of CT images and can overlap the root of the teeth and simulate root fractures. It may occur in CT scans, sometimes making diagnosis unusable.\textsuperscript{1,13,24} CBCT in teeth with intracanal retainers can design ghosting and mask the actual structure of the root canal, which limits the interpretation, reduces the image quality and increases the risk of misdiagnosis.\textsuperscript{13,24}

Estrela et al.,\textsuperscript{15} in 2011, reported the effect caused by the intracanal posts on the images dimensions from CBCT in endodontically treated teeth. human teeth were used and distributed in five groups, according to the material used (glass fiber, carbon fiber, prefabricated metal, silver, and gold). The root canals were prepared, filled, partially removal of gutta-percha and prepared to intracanal retainers. The results showed that the dimensional values measured on CT scans of retainers of high density, such as gold and silver, are higher than the measurements of specimens. Hardening beam can be seen depending on the intracanal retainer type. These results have important clinical implications, especially if artifacts overlapping parts of the root and mimic or mask pathologies. Image interpretation of CBCT reconstructed teeth with intracanal retainers should be taken cautiously, justifying the use of periapical radiographs as a reference for endodontic diagnosis.

The inability to correctly locate the root perforation position can lead to clinical failures, directly affecting the prognosis of the case. Bueno et al.,\textsuperscript{24} in 2011, emphasized, through the presentation of clinical cases, the strategy used to minimize the formation of image artifacts. Reading the different CT slices provides valuable information showing display and location traces toward the communication point between root canal and periodontal space, associated with radiolucent areas, suggesting root perforation. Analyzing the clinical cases presented and it was concluded that the formation of metallic artifacts associated with perforations are potential risks of misdiagnosis, especially when he suggests root perforation or destruction. The materials used for root canal filling may also contribute to image artifacts formation. This is because of the high density of the filling material conduit. Decurcio et al.,\textsuperscript{44} in 2012, evaluated the filling materials discrepancy using samples of original roots and the CBCT images. For that, 72 anterior teeth were prepared, filled, and separated based on the type of
Assessment of Root Canal Anatomy (Number of Canals and Isthmus)

In several studies, CBCT imaging was superior in detecting the number of roots to conventional the periapical radiographs.\textsuperscript{46-48} CBCT reconstructions are somewhat important in assessing teeth with an unusual number of roots, dilacerated teeth, and dens in dente. Root morphology (the number of root canals and whether they merge or not) can be visualized 3D\textsuperscript{46-48} (Figures 2a-c).

Reis et al.,\textsuperscript{48} in 2013, investigated the presence of second mesiobuccal canals in different thirds of the mesiobuccal root of the first and second maxillary molars using CBCT scanning and to correlate findings with patient sex and age. A total of 100 male and female adult patients with healthy, untreated, well-developed maxillary molars were enrolled. A total of 343 teeth were analyzed in vivo using CBCT scanning: 79 right and 79 left maxillary first molars and 94 right and 91 left maxillary second molars. Teeth with 3 roots were identified, and the presence of second mesiobuccal canals in different thirds was correlated with patient sex and age. The maxillary molars with 3 roots showed a high percentage of second mesiobuccal canals: Right maxillary first molars (86.1%), left maxillary first molars (91.0%), right maxillary second molars (87.5%), and left maxillary second molars (79.3%). The second mesiobuccal canals were less prevalent in the middle and apical thirds than in the coronal third. There were no significant associations between the overall presence of second mesiobuccal canals and patient sex. All age groups showed fewer second mesiobuccal canals in the apical versus the coronal third. The prevalence of second mesiobuccal canals decreases as the root canal approaches the apical third and as age increases. No association with sex was observed. CBCT scanning proved effective in mapping second mesiobuccal canals present indifferent thirds of the root.

In recent years, there has been increased interest on root isthmus area and its influence on the root canal treatment. The isthmus may be considered as a narrow extension from either one or two main root canals, subdivided in incomplete or complete\textsuperscript{50} (Figures 2d-f).

Pécora et al.,\textsuperscript{50} in 2014, studied the presence of root isthmuses in maxillary and mandibular molars and evaluate their frequencies using map-reading dynamics in CBCT images. Two hundred extracted human maxillary and mandibular molars were used in ex vivo assay. A consecutive sample of 200 maxillary and mandibular molars (first and second) was selected from CBCT examinations. The isthmuses were detected from the pulp orifice to the apex and were recorded according to their beginning and their end, into categories: 1 - Begin and end in cervical third; 2 - Beginning in cervical third and end in middle third; 3 - Beginning in cervical third and end in apical third; 4 - Beginning and end in middle third; 5 - Begin in middle third and end in apical third; 6 - Beginning and end in apical third; 7 - No isthmus. The scans were obtained in different planes with map-reading in axial slices of 0.5 mm/0.5 mm involved the coronal to apical direction. The frequencies of isthmus...
were analyzed according to the level of root and evaluated by Chi-square test. The level of significance was set at $\alpha = 0.05$. The presence of isthmus detected in maxillary molars was 86% in ex vivo assay and 62% in vivo assay, whereas in mandibular molars were observed 70% in ex vivo assay and 72% in vivo assay. The frequency of isthmus was high in both study models. The map-reading dynamics in CBCT images were found to be precise to detect the localization of isthmus.

**Discussion**

Challenging clinical situations require additional resources for the development of diagnosis, and consequently, improved prognosis. Diagnosis of periapical pathology is a problematic in worldwide and this condition may affect quality of life, even causing morbidity in certain cases. Studies have shown a high prevalence indicating the necessity of the permanent process of professional scientific update, longitudinal control of endodontic treatments and promoting prevention campaigns prevention of dental caries and trauma, as well as investments in scientific and technological development applied to endodontics. In this context, a fast and accurate diagnosis is the key to success of endodontic treatment. Besides the previous history and clinical examination, it becomes necessary complementary imaging tests. The periapical and panoramic radiographs are still the most used in endodontic procedures, providing useful information for the clinician. Nevertheless, these tools have limited information that can influence the radiographic interpretation. The literature is unanimous in citing the lack of information in the 3D and interest areas masked by overlapping structures in the images interfere in making the diagnosis. The radiographic interpretation is influenced by the variation of apical region morphology, bone density, angle of X-rays, contrast, and actual location of the periapical lesion. Thus, it is not always possible to diagnose problems such as endodontic root fractures, dental resorption, and changes in the apical region through conventional radiographic methods. There is complexity to diagnose the presence and extent of lesions in the medullary bone due to the limitations of 2D image of a 3D object and the superimposition of anatomical structures. According to studies by Laux et al., in 2000, conventional radiographs are not sufficiently accurate in the diagnosis of apical resorption compared to microscopic findings a closer examination of the tooth is needed.

The limitations regarding the periapical inflammatory diagnosis processes in the initial phase using conventional radiographic methods are reported and explained in scientific researches. For the bone rarefaction image starts to appear in a periapical radiographic examination, need the requirement to a bone density loss ranging from 30% to 50%. The limitations of periapical radiographs in the diagnosis of resorption can be seen in certain locations, extensions, and early stages, due to the size of the lesion, according to research. The advent of CBCT introduced new paradigms and rewrote the history of endodontics that certainly benefited numerous diagnostic and planning activities. CBCT is useful in the differential diagnosis between presurgical pathologies, endodontic, and nonendodontic. Also indicated to evaluation of alveolar root fractures, morphology and location, analysis of internal and external resorption, endodontic planning, to assess the preparation, filling, retreatment, detection of bone lesions, and endodontic research. The pathologies of endodontic origin are closely related to failure, mainly due to the difficulty in diagnosing them by radiographic techniques. The diagnosis of periapical lesions can be made with greater accuracy. Using unique characteristic of better evaluation of 3D images, better diagnosis of periapical lesions, as well as good outcomes in the assessment of lesions and periapical repair. Some studies have found that regardless of the brand used, among the most cited trademarks: NewTom 3G and Accuitomo 3DX, the CBCT is superior in visualization of rarefactions and perforation even if sometimes appear imaging artifacts periapical. In 2006, argued that conventional periapical radiographs, contrast media, among other methods, are not capable of diagnosing pre-operative periapical lesions. On the other hand, Balasundaram et al., in 2012, in their study reported that both CBCT and periapical radiographs succeeded in relation to the diagnosis and prognosis of endodontic therapy. Both techniques allowed the analysis of the size and extension of the lesion and according to this findings, it can apply for an appropriate treatment plan.

When comparing the diagnostic ability by different radiographic techniques, there is an improvement in the quality of comparison. Even comparing radiographic analysis with microscopic examinations, or mainly by analyzing diagnostic capacity different techniques. In endodontics, the CBCT is important in the diagnosis of radicular fractures and endodontic problems and recently has been used for the pre-operative planning due to the exact nature and severity of alveolar injury. Bornstein et al., in 2011, recommend the verification of CBCT in pre-operative surgical cases, thus demonstrating the importance of the application of this method in periradicular surgery. The CBCT is more prevalent in the planning of endodontic surgery, it is not necessary to have cortical bone destruction for viewing erosion in cancellous bone. Besides providing information about the thickness of cortical bone, correct position neurovascular bundles and spatial relationship of the important noble structures, CBCT allows better planning and further safety in surgery. Image artifacts also manifest as existing limitations in CT scans. The difficulty in the diagnosis of root fractures in periapical radiographs was overcome by CBCT. A major reason that hinders the detection of traumatic injuries is the angle of the X-rays. On occurrence of this problem, the radiographic examination should be thorough, since the
prognosis is closely related to the visualization of the fracture line.\textsuperscript{22} Bernades \textit{et al.},\textsuperscript{22} in 2009, have studied the identification of root fractures with CBCT and in both works the CBCT stood at diagnosis. Besides identifying fractures, allowed observing the location and extent thereof, which significantly increases the diagnostic quality.\textsuperscript{23}

Low \textit{et al.},\textsuperscript{35} in 2008, compared periapical radiography with CBCT. According to them, some lesions and resorption were not diagnosed with periapical radiography, due to the 2D aspect of the technique. Image overlay limits the diagnosis by conventional methods, agreeing with the study by Estevez \textit{et al.},\textsuperscript{42} in 2010. Patel \textit{et al.},\textsuperscript{41} in 2009, and Estevez \textit{et al.},\textsuperscript{42} in 2010, asserted that conventional radiographs are not accurate enough to enable the detection of resorption and also do not increase the probability of choosing the correct treatment. Many studies point to the overlay, one of the main factors. Laux \textit{et al.},\textsuperscript{40} in 2000, reported that periapical radiography is not effective in diagnosing apical resorption compared to other tests and that further examinations are required. Thus, with the applicability of CBCT in endodontics, it is possible to identify changes in the early stages and in different angles.\textsuperscript{5,14,17}

The results of the studies showed that there is a notorious diagnostic ability of CBCT, which confirms the results from the use of conventional CT, until recent years with CBCT.\textsuperscript{24,26,35,46} Another factor that complicates treatment in endodontics refers precisely the complexity of the root canal system and knowing the internal anatomy as well as the degree of curvature and how to identify potential anatomical changes become necessary.\textsuperscript{21} Accordingly, a method has been proposed for the radius of curvature of the root.\textsuperscript{21} Estrela \textit{et al.},\textsuperscript{29} in 2008, employed CBCT technology concluding that according to the results, this new technology favors treatment planning, allowing identify abnormalities that could interfere with the success of therapy.

When all the features of radiographic techniques were utilized and doubt persists, the use of CBCT imaging with 3D is indicated and represents a major advance for clinical diagnosis, both low dose of radiation and the magnification 3D image.\textsuperscript{2,19,26,37} Even with the high image resolution, fast acquisition, better visualization of anatomic structures, with appropriate imaging geometry and contrast, diagnosis in greater detail, it must be noted the higher cost and formation of image artifacts, which contributes poorly to diagnostic accuracy.\textsuperscript{1,10,26,42,46,47} Among other advantages, CBCT allows only obtain images of the area of interest, compaction apparatus, reduction of scanning time when compared to conventional periapical radiographs.\textsuperscript{11,13,18,34} The size of the visual field is also an indispensable factor for better details on CT images.\textsuperscript{23,24} Costa \textit{et al.},\textsuperscript{15} in 2011, and Özer\textsuperscript{37} in the same year, conducted studies that indicate the importance of working with small volume tomography in endodontics, this is mainly due to a significant decrease of radiation beyond the best image resolution, the small focal spot. The inclusion of the 3D, the use of computing and imaging without distortion made CT a great allied for diagnostic purposes, leading to a rapid and significant growth of these tests within endodontics.\textsuperscript{5,14,17} This led, in 2012, the establishment of a guide to indication of CBCT in endodontic treatment, based on scientific research, on the commitment of that document be revised periodically reflecting new evidence.\textsuperscript{11} In fact, although the CBCT has many advantages compared to periapical radiograph, its routine use is not encouraged and the criteria for patient selection are based on the pillar of radiological radiology (Principle of Alara), where the benefits outweigh the risks.\textsuperscript{8,10,11,13,17} Patient’s medical history and clinical examination must justify the use of this exam.\textsuperscript{3} The clinician should indicate this method when the conventional images do not adequately answer the questions relevant to the process of diagnosis and endodontic treatment.\textsuperscript{5,11,13,17} Knowledge and use of new techniques are partners of success, but more importantly, must be combined with responsibility and respect for patients, essential factors for successful treatment.

References


