

Cone-Beam CT Diagnostic Applications: Caries, Periodontal Bone Assessment, and Endodontic Applications

Donald A. Tyndall, DDS, MSPH, PhD* ,
Sonali Rathore, BDS

*Division of Oral and Maxillofacial Radiology, University of North Carolina
School of Dentistry, Brauer Hall, Chapel Hill, NC 27599-7450, USA*

In this issue of *Dental Clinics of North America*, cone-beam computed tomography (CBCT) applications in dentistry are examined. This article focuses on applications of CBCT to dentoalveolar disease and conditions, as applied in the practice of general dentistry, periodontics, and endodontics.

The technology of CBCT is described elsewhere in this issue of *Dental Clinics* and will not be repeated in detail here. It suffices to say that CBCT is a new application of CT that generates three-dimensional (3D) data at lower cost and absorbed doses than conventional CT found in the practice of medical radiology. Data from the craniofacial region are often collected at higher resolution in the axial plane than those from conventional CT systems [1]. In addition, these systems do not require a large amount of space and can easily fit into most dental practices today.

Most of the attention regarding CBCT imaging has focused on applications for dental implant placement, orthodontics, surgery, and temporomandibular joint imaging [2–8], and not as much emphasis has been placed on the applications of CBCT to dentoalveolar conditions and treatment. This article reviews and examines the available evidence from the clinical and scientific literature pertaining to dentoalveolar tasks, primarily limited to three basic areas: (1) caries diagnosis, (2), detection and characterization of the bony aspects of periodontal disease, and (3) endodontic applications, including the diagnosis of periapical lesions due to pulpal inflammation, visualization of canals, elucidation of internal and external resorption, and detection of root fractures.

* Corresponding author.

E-mail address: don_tyndall@dentistry.unc.edu (D.A. Tyndall).

The chief limitation of current conventional intraoral and panoramic imaging for these common dentoalveolar diseases is the problem of conspicuity [9], which is largely the result of the representation of a 3D structure depicted by a two-dimensional (2D) image. This limitation is true for caries [10] and periodontal [11] and endodontic applications [9]. Dentistry has largely used the same method of 2D imaging since the first intraoral radiograph obtained in 1896. In fact, on close examination, only one or two significant advances in dental imaging have been made since then. These advances include panoramic imaging and tomography, with the former being far more useful for dental applications, and the latter historically being limited primarily to temporomandibular joint and implant site imaging. Digital imaging has been an advancement, yet the imaging geometry has not changed with these commonly used intraoral and panoramic technologies.

Earlier attempts have been made to improve the diagnosis and treatment of dentoalveolar conditions with 3D imaging using variations of tomosynthesis, most notably, tuned aperture CT (TACT) imaging [12]. Although TACT provided some incremental benefit for periodontal and endodontic applications, improvements in caries detection and characterization were limited to simulated recurrent caries [13–18]. These tomosynthetic methods proved promising but thus far have found limited application in the practice of dentistry. A new type of tomosynthetic technology, based on statistical inversion methods, named volume tomography, has recently entered the dental imaging market and may prove useful. It produces a stack of 256 images depicting cross-sectional information useful for implant treatment planning, which can visualize a limited volume of 6.0 by 6.0 cm. The system is an option with an OP 200 panoramic unit (Instrumentarium Dental, Tuusula, Finland) and is lower in cost and radiation dose than CBCT systems.

By the end of the twentieth century and the beginning of the twenty-first, it has become apparent that CBCT imaging may indeed be the next major advancement in dentoalveolar imaging, providing true 3D imaging at a lower cost than conventional CT, with radiation risks similar to current methods of intraoral imaging, including panoramic and full-mouth radiographic examination [19]. The advantages of CBCT for other maxillofacial applications have been well documented in this issue of *Dental Clinics*. What follows is a review of what is known about the potential benefits of CBCT imaging as applied to dentoalveolar tasks defined in this article as caries diagnosis, characterization of periodontal lesions, and various endodontic applications.

When considering a comparison of different imaging technologies, the reader is reminded that an increase in efficacy or lack thereof does not necessarily imply superiority or inferiority. Other factors must also be considered. A consideration of the total radiation risks for current imaging modalities, and ease of use and efficiency, should be considered. An example would be comparing CBCT with a full-mouth series of intraoral radiographs

for the detection of dentoalveolar disease. CBCT would not necessarily have to demonstrate a superior diagnostic efficacy over a conventional full-mouth series of radiographs in order to be considered an improvement over conventional methods. If CBCT was equal to a full-mouth series in efficacy, it could be argued that, depending on machine type, the radiation risk would be considerably less, as would the time and effort it takes to image the patient. The reader may conclude that CBCT, under the aforementioned conditions, would actually be considered superior to conventional intraoral imaging methods. Alternative examinations such as a panoramic, with bitewings and limited periapical radiographs, might prove to have risks equal to, or fewer than, CBCT. In addition, the presence of metal effectively eliminates the possibility of caries detection in restored teeth, so CBCT may not prove practical for many patients as a general dental examination method unless it is supplemented with bitewing radiographs. Finally, *in vitro* studies involve no patient motion. Motion can, and often does, lead to CBCT image degradation. With these considerations in mind, the current literature on CBCT for caries diagnosis, periodontal bone characterization, and endodontic applications is examined, followed by a summary of what we know and can apply to current dental practice now and in the future.

Caries diagnosis

The detection of proximal and occlusal surface caries by conventional intraoral 2D methods has demonstrated only low-to-moderate sensitivity, but slightly better specificity, and high observer variability [20–26]. Pervious extraoral imaging methods for caries detection have met with limited success and dubious clinical applications. CBCT imaging appears to be the best prospect for improving the detection and depth assessment of caries in approximal and occlusal lesions. Recent work with benchtop-based local or limited CBCT (LCT) systems has demonstrated the potential for caries detection and depth characterization by high-resolution systems [10,27–30]. All five studies used a benchtop CBCT system with a high resolution (40- μm pixel) charge-coupled device (CCD) detector and rotating turntable with a fixed anode intraoral radiograph source; they also used histologically generated ground truth and small sample sizes of 24 to 30 teeth. LCT images were presented in parasagittal (similar to the bitewing view) and axial planes and were compared with bitewing radiographs. General linear model and receiver operating characteristic curves with analysis of variance methods were the statistical methods used. Kalathingal and colleagues [10] found no difference in the detection of carious lesions but did find that LCT was superior for caries depth assessment and although sensitivity increased, specificity showed no difference. The work performed by van Daatselaar and co-workers [27–30] demonstrated the superiority of LCT images for caries detection and noted that the number of source images could be as low as 14, a significant finding because a CCD detector was used for the study.

Turning to clinical CBCT systems, Akdeniz and coworkers [31] and Tsuchida and colleagues [32] used a limited-volume CBCT (LCBCT) Accuitomo device and compared *in vitro* CBCT results with either conventional film radiography or storage phosphor (SP) images. Akdeniz and colleagues, using 41 teeth, histologically verified ground truth, and all image planes for viewing found that LCBCT was superior for caries depth assessment when compared with SP and film. These results corroborated the work of Kalathingal and colleagues [10]. One possible weakness of the study was its use of only two observers.

Tsuchida and colleagues used micro-CT verified ground truth on 50 teeth with noncavitated incipient lesions, in a study where only 29 of the 100 surfaces were sound. Seven observers were used to generate receiver operating characteristic curves, which demonstrated no significant differences between the LCBCT images and film. This finding is not surprising, considering the difficulty of detecting incipient lesions.

A most recent and thorough study using full-volume CBCT and LCBCT by Haiter-Neto and colleagues [33] compared the NewTom 3G system (APF Imaging, Elmsford, New York) using three fields of view (12, 9, and 6 inches), the Accuitomo LCBCT system (J. Morita Manufacturing Corporation, Kyoto, Japan), Insight film (Eastman Kodak Company, Rochester, New York), and Digora SP (Soredex, Tuusula, Finland) images for the detection of approximal and carious lesions. Ground truth was histologically determined with 63% sound surfaces for approximal lesions and 6% for sound surfaces, with the former being the most realistic distribution of lesions to date which actually approximates interproximal caries prevalence. Six observers viewed all three fields of view for the NewTom system and all other modalities. The results showed that the NewTom 12-inch and 9-inch images had significantly lower sensitivities than the Accuitomo systems, whereas the NewTom 9-inch and 6-inch images had significantly lower specificities than the insight film and Digora images. The Accuitomo images were determined to be no different from film or the Digora-based images. For occlusal surfaces, the Accuitomo presented a higher sensitivity than the other systems. Specificity and overall true score did not differ among the modalities for occlusal lesions. The investigators concluded that the NewTom 3G system had a lower diagnostic accuracy for caries detection than the intraoral or LCBCT systems. The LCBCT systems were determined to be equal to the intraoral systems but did score higher in detecting dentinal lesions. These results are not surprising, given the lower spatial resolution of the NewTom system and the higher signal to noise ratio of the LCBCT system. Typically, the sensitivities were higher for the CBCT modalities but specificities were less, suggesting that one of the limitations of caries detection with CBCT imaging may be an increase in the number of false-positives. The investigators reminded the readers that CBCT doses for caries detection are still higher for many types of intraoral examinations, although they vary significantly, depending on which country is being studied. For instance, in the United

States, a full-mouth series of radiographs with D speed film and no rectangular collimation is the most common type of full-mouth radiographic examination. CCD-based, or even F speed with rectangular collimation, image series will be significantly less. Thus, the risks for CBCT imaging as a possible replacement for a full series of radiographs vary, depending on the system with which it is being compared.

The study did not separate the occlusal from the approximal lesions. Further studies are needed to evaluate CBCT for the detection of occlusal or pit and fissure caries, a task for which 2D imaging has been weak. In addition, the reader is reminded that in the *in vitro* studies mentioned earlier, intraoral 2D images were usually obtained under ideal geometry conditions with no closed contacts, cone cuts, or projective distortions. The equivalence of CBCT scores to those of 2D imaging may, in the minds of some, demonstrate the superiority of the former system. This point will also be considered in the conclusions. At this time, the application of CBCT imaging to caries diagnosis is promising, with more research needed, especially *in vivo* investigations. In addition, with current technology, it is assumed that teeth with metal or even radiopaque restorations should not be considered for CBCT caries imaging.

Examples of CBCT for caries imaging can be seen in Figs. 1 and 2.

Periodontal applications

In his 2004 summary of periodontal imaging methods in *Periodontology*, Mol states, “Relatively few technologies have emerged to address the critical needs in periodontal diagnosis” [11]. He goes on to point out that although digital imaging has added value to intraoral imaging, an increase in diagnostic capabilities has not been one of the benefits. Mol discusses the limitations of extraoral imaging (panoramic) with its associated drawbacks but does point

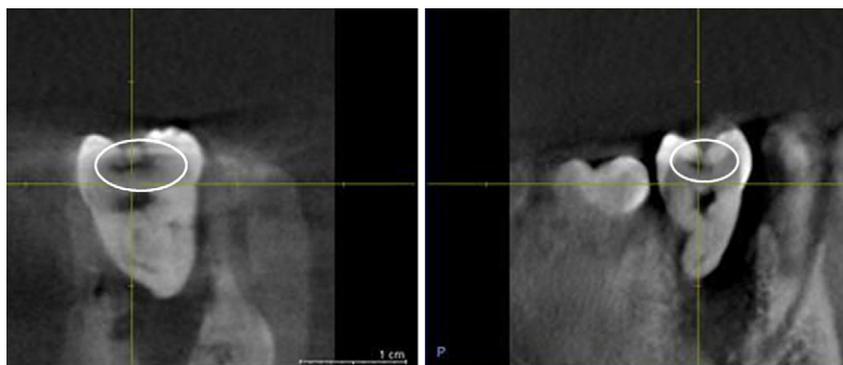


Fig. 1. Occlusal caries (circled) seen in a molar tooth from longitudinal and cross-sectional views. These images were part of an *in vitro* study using human teeth with histologically verified carious lesions. They were obtained using a 150- μ m view with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

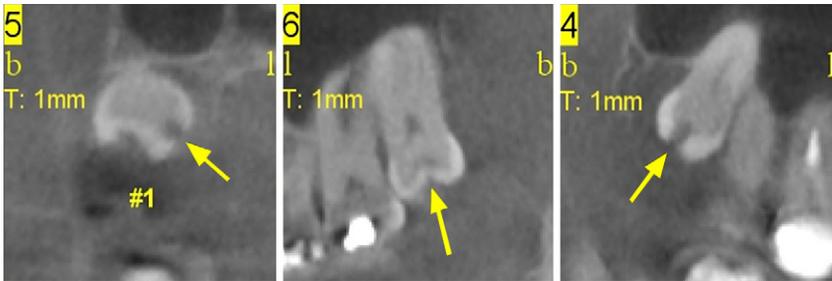


Fig. 2. Clinical caries seen in several molar teeth (*arrows*). These 300- μ m images were obtained using the NewTom 3G system (APF Imaging Corp., Elmsford, New York).

out the usefulness in association with bitewings and selected periapicals. Mol also reviews the more advanced digital technologies, such as TACT, digital subtraction, and conventional CT scanning, and states their potential for an increase in diagnostic efficacy and characterization of the periodontal bone status. He concludes by outlining the practical limits of these technologies and explains why they are not going to be particularly useful in the practice of dentistry [11]. Previous studies have shown that CT assessment of alveolar bone height and bony pockets is reasonable, accurate, and precise [34–37]. Mol states that CBCT studies applied to periodontal imaging were in progress and not available at the time of publication of his review. Several of these studies are now available. Most studies investigating the application of CBCT imaging to periodontal bone status are *in vitro*, although a few are *in vivo*, with either full-volume CBCT or limited-volume units used.

Vandenberghe and coworkers [38] investigated periodontal bone architecture using 2D CCD and 3D full-volume CBCT-based imaging modalities. Periodontal bone levels and defects were assessed and evaluated against two human skulls' gold standard. Visualization of lamina dura, crater defects, furcation involvements, contrast, and bone quality were also evaluated. They concluded that CBCT image measurements of periodontal bone levels and defects were comparable to intraoral radiography. It was found that CBCT images demonstrated more potential in the morphologic description of periodontal bone defects and conversely, the CCD images provided more bone details. Using a dry skull with artificial defects and full-volume CBCT, Misch and colleagues [39] found similar results. Their investigation demonstrated that CBCT was as accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas. In measurements of buccal and lingual defects, CBCT proved superior to conventional radiography. Because of this finding, the investigators concluded that CBCT offered a significant advantage over conventional radiography.

In a 2005 study using human and pig material, Mengel and coworkers [40] investigated the use of CBCT in the diagnosis of periodontal defects using intraoral radiography, panoramic radiography, CT, and LCBCT in comparison with histologic specimens. It was demonstrated that all

intrabony defects could be measured in three planes in the CT and LCBCT scans with great accuracy true to scale, whereas only mesial, distal, and cranio-caudal plane defects could be detected by intraoral and panoramic imaging. It was also concluded that the LCBCT system produced higher-quality images. Noujeim and coworkers [41] found similar results when using the LCBCT system to detect simulated interradicular lesions of varying depth in comparison with intraoral radiography. Two studies in linear accuracy have recently been published by Loubele and colleagues and Mol and colleagues [42,43]. Loubele and coworkers designed a study to compare the accuracy of LCBCT with multislice CT for linear measurements with caliper-determined measurements using cadaveric materials. They concluded that both systems were accurate with submillimeter measures. In a study directed more to periodontal defects, Mol, using an older form of CBCT using a full field of view, found that CBCT images provided better diagnostic and quantitative information on periodontal bone levels in three dimensions than conventional radiography. The study also demonstrated a limitation in that the accuracy in the anterior aspect of the jaws was limited. The system used a NewTom 9000 unit (APF Imaging, Elmsford, New York), generating images that were inferior in quality to what more up-to-date systems can generate.

The fact that these studies used full-volume CBCT and limited-volume systems hints that either system may be more capable than intraoral radiography in the visualization of periodontal bone architecture. The reader is reminded that motion can cause image degradation and that all the studies mentioned are *in vitro* and are not subject to the less than ideal clinical situation [44]. At the same time, intraoral radiography is featured in ideal conditions in these *in vitro* studies.

In a recent review of currently published literature on CBCT for periodontology, Kasaj and Willershausen [45] conclude that the low dosage and superior image quality in comparison with conventional CT are promising for periodontal applications, especially in the areas of intrabony defects, dehiscence and fenestration defects, and periodontal cysts, and in the diagnosis of furcation-involved molars. This summary encapsulates the findings of the studies discussed earlier. Overall, these studies suggest that CBCT imaging has the potential to replace intraoral imaging for the assessment of periodontal architecture. However, clinical studies would be helpful in supporting this conclusion. CBCT may be a useful and more practical clinical tool than digital subtraction radiography for the assessment of changes in periodontal bone over time. Examples of CBCT for periodontal imaging can be seen in Figs. 3 and 4.

Endodontic applications

It is in the area of endodontic applications that the literature has proved most fruitful to date. Endodontic applications include the diagnosis of periapical lesions due to pulpal inflammation, visualization of canals,

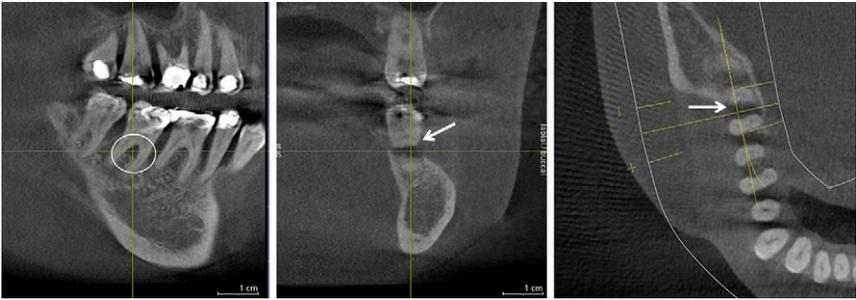


Fig. 3. Three images depicting a complete periodontal furcation involvement of a second molar. The figure on the left visualizes a furcation involvement delineated by the circle. The center and right images demonstrate the extent of the lesion (*arrows*) from facial-lingual and axial views. These 300- μ m images were obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

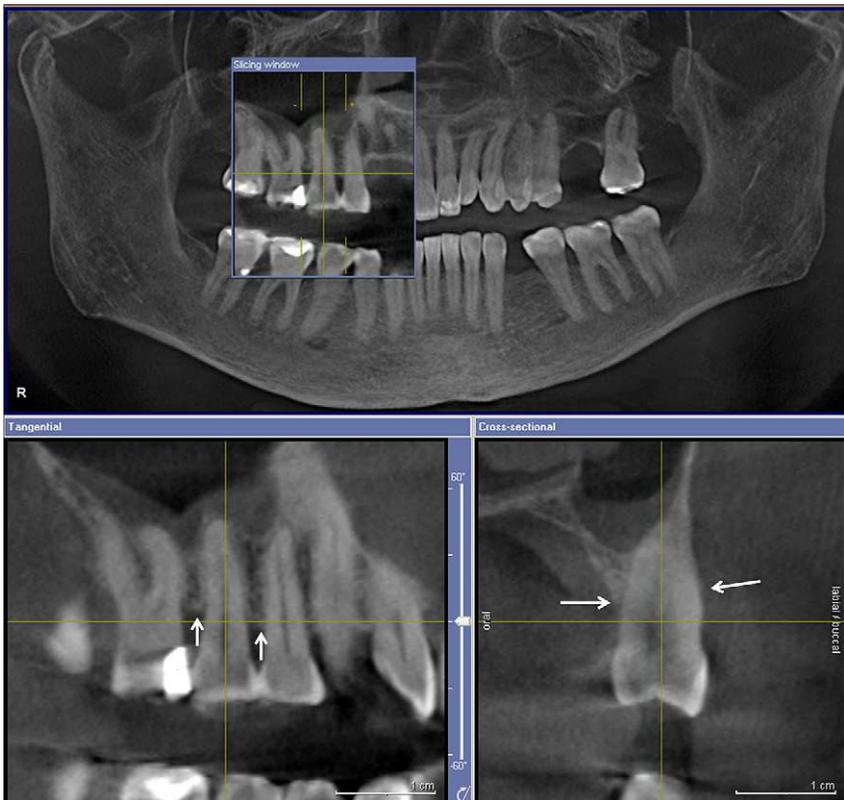


Fig. 4. Three-dimensional depiction of periodontal bone loss around a maxillary second premolar tooth. The arrows indicate the extent of bone loss on the facial, palatal, mesial, and distal aspects of the tooth. These 300- μ m images were obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

elucidation of internal and external resorption, and detection of root fractures. As is the case with the previous two categories, most published articles are either case reports or *in vitro* studies.

Current 2D technologies are film and digital based. Stavropoulos and Wenzel [46] remarked in a recent article that the two have few, if any, differences. The investigators do point out that digital enhancements may result in limited improvement in detection. The classic study by Bender and Seltzer [47,48] demonstrated the limitations of intraoral radiography for the detection of periapical lesions. Their study revealed that in order for a lesion to be visible radiographically, the cortical plate of bone must be engaged. Many subsequent studies since that time have underscored the difficulty of detecting periapical lesions. These radiographic limitations are summarized in a review by Huuonen and Ørstavik [49], in which they state that such limitations exist, in part, because radiographs are 2D in nature and clinical or biologic features may not be reflected in radiographic changes.

Evidence is compelling that these limitations may be overcome through CBCT imaging. It is reviewed below.

A review of digital and 3D applications for endodontic uses recently published by Nair and Nair [50] summarized the CBCT portion by stating that such technology has proved useful for localization and characterization of root canals, treatment planning of periapical surgery, and detection of root fractures in extracted teeth. This last topic was explored in a recent *in vitro* study by Mora and coworkers [51], who used a benchtop high-resolution LCBCT device to demonstrate the superiority of this technology over conventional 2D imaging. Basis image sets of 180, 60, 32, and 20 were used and all but the 20 image group proved more accurate. The investigators point out that this study used a high-resolution CCD detector currently not used by any existing CBCT system.

In a clinical study conducted by Simon and coworkers [52], CBCT was found to be useful in differentiating solid from fluid-filled lesions (periapical granulomas from cysts) using grayscale values in the lesions. This information would presumably enable the clinician to manage the lesion in question more effectively. This study was one of the few that was clinical in nature and verified by histologic analysis. Of the total 17 lesions, 13 were correctly identified by CBCT. Of the remaining lesions, the investigators felt that the CBCT results were actually more accurate than the microscopic analysis because of poor biopsy sampling. Another clinically based publication, by Cotton and coworkers [53], featured a series of case reports demonstrating the usefulness of high-resolution LCBCT of endodontic applications. Such applications included identifying an untreated canal that had resulted in root canal treatment (RCT) failure, identifying a nondisplaced root fracture, identifying the extent of internal resorptions not seen on periapical radiographs, visualizing extruded RCT material in the mental nerve canal, and a few other applications. In all cases, the 3D nature of the CBCT images

revealed aspects of a periapical or tooth area that had a positive influence on the clinical outcome. Although this study was not scientifically controlled, it did point to the various potential uses of CBCT for endodontic diagnosis and applications. A recent case report by Maini and coworkers [54] demonstrated the benefit of CBCT in identifying resorption of a tooth contacted by an impacted canine. In this case, orthodontics was not used and an alternative treatment plan was generated. In their article, the investigators pointed out that CBCT studies have shown that 68% of impacted canines cause root resorption of adjacent teeth, up from 12%, as determined from previous 2D studies [55].

Further clinical applications were demonstrated by Rigolone and coworkers [56] in a clinical study using large-volume CBCT as an aid in apicoectomy surgery involving the palatal root of a maxillary molar. In this clinical study based on 31 patients, CBCT was effective in identifying an alternative and less invasive surgical approach using a vestibular, as opposed to a palatal, approach in combination with an operating microscope. Tsurumachi and Honda [57] described the use of LCBCT in localizing a broken endodontic instrument in the maxillary sinus in yet another application for endodontic practice.

Patel and coworkers [58] reviewed the literature on CBCT applications to endodontics and found CBCT to be clinically superior to periapical radiography for the detection of periapical lesions. They cited an interesting study by Lofthag-Hansen and coworkers [59], in which CBCT was found to result in 62% more periapical lesions on individual roots being identified, when compared with periapical examinations. In addition, Patel and colleagues found CBCT to be efficacious in endodontic surgery, periapical surgery treatment planning, identification of root canals not seen on 2D images, identification of dentoalveolar trauma, and the management of external cervical root resorption. Furthermore, the investigators posit that one of the most important applications of CBCT imaging for endodontics may be in the assessment of treatment outcomes. They argue that the greater geometric accuracy of CBCT scans should prove superior to conventional imaging of treatment follow-through and the assessment of healing post-RCT.

Several important *in vitro* studies have been conducted that apply CBCT imaging to other endodontic applications [46,60]. In 2007, Sogur and colleagues [60] conducted a study comparing the subjective image quality of root canal fillings among LCBCT, SP, and film radiography. In that study, CBCT was found to be inferior to 2D digital radiographs because of the limitations of streaking artifacts. Finally, in the previously cited *ex vivo* investigation by Stavropoulos and Wenzel, a large-format CBCT system was compared with 2D digital and film images for the detection of simulated periapical lesions in pig jaws. In that study, cylindrical defects of 1 mm × 1 mm, 2 mm × 2 mm, and 3 mm × 3 mm were randomly prepared beyond the apices of extraction sockets. Control sites were also included. Blinded examiners were used. CBCT images proved statistically superior in sensitivity,



Fig. 5. In this case, the standard 2D periapical radiograph did not reveal the true extent of the apical lesion (*circle*). The pattern of the lesion suggests a root fracture (*arrow*). In this case, the treatment of the tooth was changed from re-treating the root canal to extracting the tooth. These 300- μ m images were obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).



Fig. 6. In this case, a patient had a 3- to 4-month history of intermittent pain associated with a recently placed crown restoration. Multiple periapical radiographs were obtained but showed no evidence of a periapical lesion. The most recent periapical radiograph is shown on the left. The center and right figures are CBCT images that clearly depict a periapical lesion extending into the maxillary sinus. The circled areas indicate the lesion. Note also that most of the facial cortical plate of bone is preserved, possibly explaining why the lesion failed to appear on the periapical radiographs. These 300- μ m images were obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

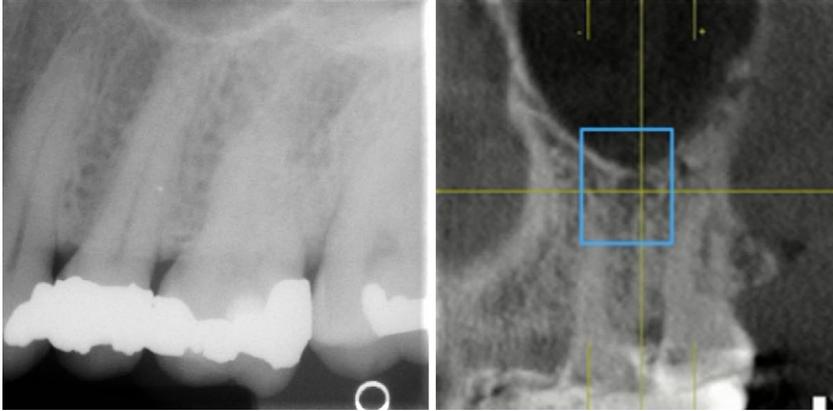


Fig. 7. In a case similar to Fig. 6, this patient had intermittent pain and returned to the clinic for repeated periapical radiographs, all of which were negative, as seen in the image on the left. The right image depicts the CBCT view of a small but definitive periapical lesion. In both cases, RCTs solved the patient's tooth-related problems. Figs. 6 and 7 are good examples of the limited diagnostic benefits of high-resolution 2D images. Despite having a lower resolution, the CBCT images were superior to the periapical radiographs for diagnosing the problems. These 300- μ m images were obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

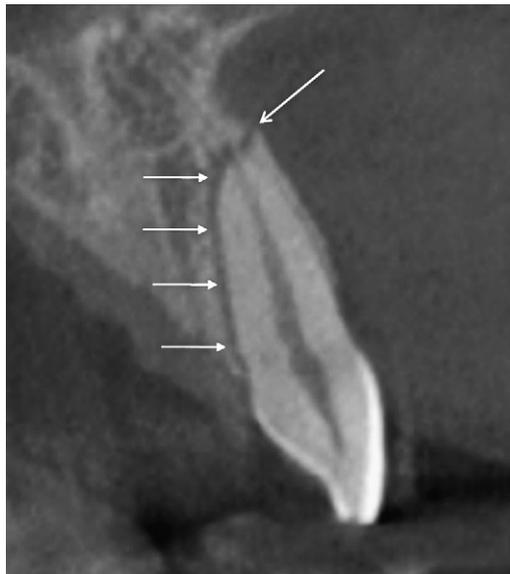


Fig. 8. This patient was struck in the mouth and suffered a facial cortical plate fracture (*open arrow*). This image demonstrates the usefulness of CBCT in assessing dentoalveolar trauma. In addition, a widened periodontal ligament space is visualized (*closed arrows*) on the lingual aspect, which most likely represents subluxation of the tooth. This 300- μ m image was obtained with the Sirona Galileos CBCT system (Sirona Dental Systems, Bensheim, Germany).

positive and negative predictive values, and diagnostic accuracy when compared with the 2D modalities. Specificity was similar for all three methods.

In summary, *in vivo* and *in vitro* investigations demonstrate the superiority of CBCT to conventional imaging for almost all endodontic applications, except for assessing the quality of root canal fills. Although most studies were *in vitro* and were observational in nature, the usefulness of CBCT over 2D imaging was demonstrated. Of course, dose and costs must come into consideration when deciding the most appropriate selection criteria for CBCT imaging. Here, as in the other dentoalveolar applications, the reader is reminded that no double blind clinical trials or studies with other, more robust, *in vivo* research methodologies have taken place. However, such studies are time consuming and expensive and generally use technologies that are out of date by the time of publication; hence, the profession is left with less than ideal studies on which to base selection criteria decisions. The *in vitro* evidence is compelling but, again, the reader is reminded that these studies have no motion, which is perhaps balanced by the fact that 2D studies are undertaken with ideal imaging geometries that are seldom achieved in the clinic. Examples of CBCT for endodontic applications can be seen in Figs. 5 to 8.

Summary

In summary, several important points should be considered:

1. Only a modest amount of research has been undertaken in the field of CBCT and dentoalveolar applications. Certainly, more *in vivo* and *in vitro* studies are needed for this field to reach full maturation. More clinical studies are needed, preferably random double blind clinical trials. In addition, the effect of motion needs to be assessed for all three categories of dentoalveolar tasks surveyed in this article.
2. CBCT and caries research results are mixed for proximal caries and few data exist for occlusal and pit and fissure caries at this time.
3. CBCT imaging for caries should be limited to nonrestored teeth. Even so, we still do not know the effect of beam hardening on producing possible artifacts and false-positives. Apparently, sensitivity may increase with CBCT but it should not be at the cost of specificity.
4. As for periodontal disease, CBCT promises to be superior to 2D imaging for the visualization of bone topography and lesion architecture but no more accurate than 2D for bone height. This factor should be tempered with an awareness that restoration in the dentition may obscure views of the alveolar crest.
5. CBCT for endodontic purposes appears to be the most promising use of CBCT, in many instances instead of 2D images. Applications would include apical lesions, root fractures, canal identification, and characterization of internal and external root resorption.

Evidence is strong that CBCT imaging potentially could replace 2D intraoral imaging for most dentoalveolar tasks, especially in endodontic and periodontal applications. This possibility is especially worthy of consideration because mere diagnostic equivalency of CBCT and 2D systems may favor the former because imaging is faster and accompanied by fewer problems of geometric distortion. When considering such a shift in imaging strategy, dose and costs must come into consideration, balanced with the perspective that most CBCT studies are easier to perform in a dental office when compared with a full-mouth series of radiographs, or perhaps even a panoramic radiograph with bitewings and selected periapical images. In the United States, the radiation risks from many CBCT systems would be below those for the most common intraoral full-mouth series examination [19], which suggests that it may be possible, with the appropriate use of CBCT technology and selected intraoral images, to gain more information about dentoalveolar conditions and treatment with fewer risks and time, benefiting both the patient and the dentist. These postulates assume an increase in the availability of CBCT systems and a reasonable speed with which the dental profession adopts the technology. No doubt, future improvements in CBCT technology will result in systems with even more favorable diagnostic yields and lower doses. If a drop in prices occurs, then an age where CBCT imaging is the primary form of dental imaging may dawn. For now, CBCT imaging, like its medical counterpart, can be seen as a highly useful and, with some tasks, indispensable part of the dental imaging armamentarium.

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