

REVIEW ARTICLE

# Imaging Techniques in Endodontics: An Overview

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## ABSTRACT

This review provides an overview of the relevance of imaging techniques such as, computed tomography, cone beam computed tomography, and ultrasound, to endodontic practice. Many limitations of the conventional radiographic techniques have been overcome by the newer methods. Advantages and disadvantages of various imaging techniques in endodontic practice are also discussed.

**Key words:** Computed tomography, cone beam computed tomography, cone beam volumetric tomography, endodontics, radiovisiography, ultrasound

## INTRODUCTION

Radiographs are the most accurate and least subjective diagnostic aids available to endodontists for diagnosis of diseases affecting the maxilla and mandible. Conventional X-rays using an analog film or digital receptor produce two-dimensional (2D) image of a three-dimensional (3D) object. The anatomical structures surrounding the tooth, superimpose and make it difficult to interpret

the conventional X-ray image.<sup>[1-3]</sup> Radiographs are an important part of root canal therapy, especially for diagnosis, treatment, and follow-up. However, routine radiographic procedures do not accurately demonstrate the presence of every lesion, the real size of the lesion or its spatial relationship with the anatomical structures.<sup>[4]</sup> Newer imaging techniques in use include: Digital imaging systems (Direct, Indirect, Optically scanned), Computed tomography (CT), Tuned aperture computed tomography (TACT), Localized computed tomography (micro-computed tomography), Ultrasonography, Magnetic resonance Imaging (MRI), Radioisotope imaging, Single photon emission computed tomography (SPECT), Positron emission tomography (PET), Cone beam volumetric tomography (CBVT), Radiovisiography (RVG), and Denta scan.<sup>[5-7]</sup>

Imaging plays an important role in endodontics and is routinely utilized for the following diagnosis [Table 1].

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The improvements in imaging technology have helped in obtaining a near perfect image for accurate diagnosis. Advantages and disadvantages of various imaging techniques in endodontic are presented.

### Ultrasound in endodontics

Ultrasound (US) and Magnetic resonance imaging do not expose patients to any radiation. Ultrasound uses sound waves with a frequency outside the range of human hearing (20 kHz) and can be used to view normal and pathological conditions involving the bones and soft tissues of the oral and maxillofacial regions.<sup>[8]</sup> US is a valuable technique that can be used in place of conventional X-rays as it has a greater ability to differentiate between cystic and non-cystic lesions.<sup>[9]</sup> The alveolar bone appears as a total reflecting surface (white), if healthy; the root contours of the teeth are even whiter (hyperechoic). A fluid-filled cavity in the bone appears as a hypo-reflecting surface (dark). The degree of reflection depends on the clarity of the fluid (hypoechoic). A simple serous filled cavity has no reflection (anechoic or transonic). Solid lesions in the bone have a mixed echogenic appearance, which means their echoes are reflected with various intensities (shades of gray). If the bone is irregular or resorbed in the proximity of the lesion, the scan is seen as an inhomogeneous echo. If the bony contour limiting a lesion is reinforced, then it is very bright.<sup>[10]</sup>

Ultrasound in dentistry is used for the detection of fractures in the facial region, to detect parotid lesions during fine needle aspiration cytology, to assess the content of the lesions before surgery [Figure 1].<sup>[11]</sup> However, US is difficult to use in the posterior region of the oral cavity, because the thick cortical plate in the posterior region prevents ultrasound waves from traversing easily. Results of selected ultrasound studies are summarized in Table 2.

### Radio visiography

One of the direct digital radiographic techniques used in dentistry is radio visiography (RVG). This system is based on digital image capture with a charged coupled device (CCD) capable of image enhancement using up to 256 shades of gray. RVG was first commercially used in the United Kingdom in 1989; since then it has undergone several changes.<sup>[25]</sup>

Radio visiography comprises of four basic components, an X-ray unit, an electronic timer, an intraoral sensor, a display processing unit (DPU), and a printer.

### Applications of radio visiography in endodontics

Radio visiography is used for diagnosing carious lesions, measuring root lengths, and in detecting periapical pathology and root fractures.<sup>[26]</sup>

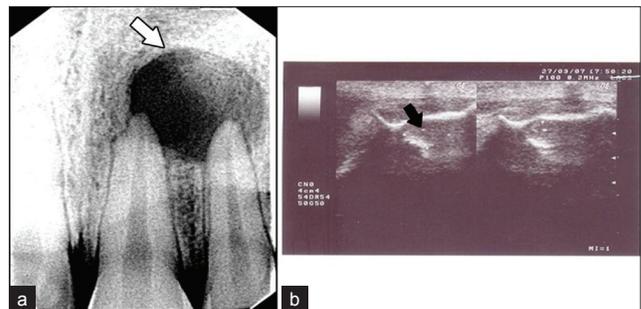
### Features of radio visiography

**Image enhancement:** The gray window effect, known as the x function, allows the operator to select and expand on a specific 60 levels of gray from the 256 available, which may aid in the diagnosis of accessory root canals.<sup>[27]</sup> The millimeter grid incorporated in the system helps in measuring the length of the root canal. The use of pseudo color assigns different colors to certain gray levels, which can help to visualize particular features that are unclear on images [Figures 2a-c].

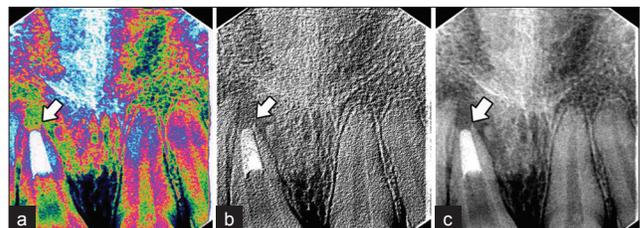
RVG requires 23% of the radiation dose when compared to the conventional radiograph.<sup>[28]</sup> Resolution of RVG is nine line pairs/mm, which is inferior to conventional X-ray films, but it is adequate for most diagnostic tasks. Advantages and

**Table 1: Role of imaging in endodontics**

Preoperative	
•	To analyze dental and alveolar hard tissue morphology
•	Pathological alterations
•	Morphology of tooth, including location and number of root canals, pulp chamber size, calcifications, root structure, direction, and curvature
•	Iatrogenic defects
•	Crown and root fractures
Intraoperative	
•	To determine the proper working length of the root canal system
•	Tooth and bone changes
Postoperative	
•	To evaluate the root canal obturation and seal
•	Tooth and periapical hard tissue changes after treatment
•	Planning for surgical considerations



**Figure 1:** (a-b) Radiovisiographic (RVG) and Ultrasound (US) images of a periapical lesion (1a) RVG image shows a well-circumscribed, radiolucent, periapical lesion with a sclerotic border, measuring about 2 x 1 cm in diameter (white arrow) (1b) USG shows a hypoechoic, well-contoured cavity, with no evidence of internal vasculature (Black arrow).



**Figure 2:** Various RVG images (a) Pseudo color RVG image shows obturation in the apical third of the root canal and resorption of the root apex. (b) 3D RVG image of a periapical lesion and root canal obturation. (c) Normal RVG image of a periapical lesion and root canal obturation.

**Table 2: Results of selected ultrasound studies are summarized**

Maity et al. <sup>[12]</sup>	Ultrasound with color power doppler is an efficient tool for monitoring bone healing as compared to the conventionally employed radiographic method.
Aseem et al. <sup>[13]</sup>	Ultrasound and color doppler imaging have the potential to supplement conventional radiography in monitoring the post-surgical healing of periapical lesions of endodontic origin.
Aggarwal et al. <sup>[14]</sup>	CT scans and ultrasound with power doppler flowmetry provide an additional diagnostic tool, without invasive surgery, where the treatment option is nonsurgical.
Rajendran <sup>[15]</sup>	The application of the ultrasound and color power doppler is a viable and nonhazardous tool for monitoring the healing of periapical lesions.
Carvalho <sup>[16]</sup>	The healing or expansion of periapical lesions can be evaluated by means of digital subtraction radiography using Adobe Photoshop CS software.
Gundappa et al. <sup>[17]</sup>	Conventional imaging and digital imaging enable the diagnosis of periapical disease, but not of its nature, while the ultrasound can provide accurate information on the pathological nature of the lesion.
Cotti et al. <sup>[18]</sup>	A tentative differential diagnosis between a cystic lesion and a granuloma can be made.
Mikrogeorgis <sup>[19]</sup>	Changes to the periapical tissue structure are easily detectable by using contrast enhancement and pseudo-coloring methods.
Scheven <sup>[20]</sup>	The ultrasound may influence odontoblast activity and dentin repair by modulating the production of endogenous growth factors in the dentin pulp complex.
Yoshioka et al. <sup>[21]</sup>	The subtraction method with direct digital radiography will be a useful tool to evaluate the healing process in endodontic treatments.
Culjat et al. <sup>[22]</sup>	An ultrasound clearly shows the 2 D contour of the dentinoenamel junction with a depth and lateral resolution of approximately 100 and 750 $\mu\text{m}$ .
William et al. <sup>[23]</sup>	When applied to intraoral images, color-coded image processing of digital images has a limited value in the estimation of periradicular lesion dimensions.
Kullendorff <sup>[24]</sup>	Subtraction radiography improves the detection of small lesions in the periapical bone area.

**Table 3: RVG - Advantages and disadvantages**

Advantages of RVG
<ul style="list-style-type: none"> <li>• Substantial radiation dose reduction</li> <li>• Production of instantaneous images</li> <li>• Control of contrast</li> <li>• Ability to enlarge specific areas that may be of use in visualizing instrument location during endodontic treatment</li> <li>• Potential for storage in a computer and subsequent transmission of the images</li> </ul>
Disadvantages
<ul style="list-style-type: none"> <li>• Loss of resolution from screen to print images</li> <li>• Relatively small sensor size</li> <li>• Greater thickness than conventional films</li> </ul>

disadvantages of RVG are summarized in Table 3. Results of selected RVG studies are summarized in Table 4.

## Computed tomography

Computed tomography (CT) produces 3D images of an object by using a series of 2D image data, to mathematically reconstruct a cross-section of the object. It is unique in that it provides images of a combination of soft tissues, bone, and blood vessels.<sup>[42]</sup> The technique of Dental CT also known as Dentascan was developed by Schwartz et al,<sup>[43]</sup> The Dental CT can be performed with a conventional CT, a spiral CT, or a multislice CT scanner.

## Application of computed tomography in endodontics

### Identification of anatomical structures

The alveolar process is the portion of the mandibular bone and maxillary bone that holds the roots of the teeth, the periodontal ligament, the periapical tissues, and the lamina dura. It is, therefore, the area of major interest in the field of endodontics, as most pathological changes, which involve the condition of the roots of the teeth, the

possible presence of foreign bodies, and the osteolytic or condensing inflammatory reactions in the bone, occur in this area. The alveolar process is easily visualized and the periodontal space can be imaged, especially if there are pathological conditions.

The extension of the maxillary sinus and the floor of the nose and their relationship with the roots of the teeth are of great importance in the study of the origin and dimension of endodontic lesions. The dental CT offers excellent visualization of maxillary sinus and adjacent teeth.

### Chronic apical periodontitis

Chronic apical periodontitis can be seen with the CT scan, both in the early and established stages. It is seen as an enlargement of the periodontal space, which is seen as a small osteolytic reaction around the root tips. Further expansion of the pathological reaction in the cancellous and cortical bone may easily be seen both on the axial scans and on the reconstructed images, including a detailed visualization of the involvement or erosion of the cortical plates.

### Vertical root fracture

CT scan is excellent in detecting vertical root fractures or split teeth as periapical radiograph can rarely detect them. CT can also be used to localize foreign bodies in the jaws.

### Diagnosis of multiple extra root canals

Extra root canals are common phenomena and missing these canals in the routine treatment can lead to endodontic treatment failure. X-rays do not give a 3D view of the anatomy. As root canals tend to lie behind each other in the buccolingual plane, they get superimposed onto each other

**Table 4: Results of selected RVG studies are summarized**

Radel et al. <sup>[29]</sup>	Kodak RVG 6000 images with enhanced contrast produced significantly lesser measurement error than unenhanced contrast Schick CDR images.
Martinez et al. <sup>[30]</sup>	None of the techniques was totally satisfactory in establishing the true working length.
Saad et al. <sup>[31]</sup>	This technique was useful in medically compromised patients, who had no need to be exposed to excessive or repeated radiation during endodontic therapy.
Sullivan et al. <sup>[32]</sup>	The accuracy of RVG with fixed contrast was not significantly different from conventional radiography with Kodak E speed films.
Mistak et al. <sup>[33]</sup>	No statistically significant differences between direct digital radiography (DDR) stored images, DDR transmitted images, and conventional film images were seen.
Kullendorff et al. <sup>[34]</sup>	Image processing had a limited effect on the diagnostic accuracy; altering of contrasts and brightness were preferred for the detection of periapical lesions.
Scarfe et al. <sup>[35]</sup>	Conventional film and RVG-S digital radiographic images for the detection of accessory / lateral canals either alone or in combination with radiopaque contrast material was low.
Ellingsen et al. <sup>[36]</sup>	Accurate identification of the position of the tips of size 8 – 10 instruments was achieved on all D and E speed radiographs with the use of magnification.
Ellingsen et al. <sup>[37]</sup>	Using RVG, identification was achieved on 95% of the zoom images in the negative to positive mode.
Yokota et al. <sup>[38]</sup>	Using RVG, the controlled adjustment of contrast in the images was now possible.
Russell et al. <sup>[39]</sup>	It could be concluded that RVG was an alternative to conventional intraoral radiography.
Shearer et al. <sup>[40]</sup>	RVG could be considered to be of equal value to conventional film radiography.
Horner et al. <sup>[41]</sup>	RVG in its present form should be considered as an adjunct rather than a replacement for conventional intraoral film.

on the periapical panoramic radiographs and easily go undetected. The software used along with the spiral / helical CT allows assessment in all three dimensions. It provides axial, panoramic, paraxial, and 3D volume rendering, which helps in diagnostic purposes [Figure 3]. Results of selected Computed tomography studies are summarized in Table 5.

### Cone beam computed tomography or cone beam volumetric tomography

Digital radiography offers the benefit of less radiation exposure, faster image acquisition, no chemical usage, and a number of image enhancement tools, such as, increasing magnification. Conventional radiography has numerous disadvantages: Inability to manipulate images, higher radiation dosage required, inability to archive images, and increased time between exposure and image interpretation.<sup>[57]</sup>



**Figure 3:** CT image shows root canal obturation and extrusion of the root canal sealer in the periapical area of the maxillary central incisor (Black arrows).

**Table 5: Summary of selected computed tomography studies**

Aggarwal <sup>[44]</sup>	Two palatal canals with separate orifices and apical foramen have been confirmed with the help of a spiral CT.
Reuben et al. <sup>[45]</sup>	The majority of the mandibular first molars have a three-canal configuration.
Ballal et al. <sup>[46]</sup>	Spiral CT is an accurate diagnostic aid in the endodontic management of unusual cases.
Gopikrishna et al. <sup>[47]</sup>	Spiral CT is an objective method to confirm the three-dimensional anatomy of the teeth.
Tasdemir et al. <sup>[48]</sup>	CT helps in accurately assessing the root canal morphology.
Zormechhingi et al. <sup>[49]</sup>	CT images show the complexities of the pulp space in primary molars.
Nance et al. <sup>[50]</sup>	The TACT system is superior to the conventional film in the detection of extra root canals in the molars.
Cotti et al. <sup>[51]</sup>	CT provide specific information about the type of lesion and the degree of bone repair after non-surgical treatment.
Youssefzadeh et al. <sup>[52]</sup>	CT is superior to dental radiography in the detection of vertical root fractures.
Vannier et al. <sup>[53]</sup>	The CT can be used for a quantitative study of oral hard tissues in the presence of metal restorations.
Nielsen et al. <sup>[54]</sup>	A micro CT accurately presents the external and internal morphologies of the tooth.
Tachibana et al. <sup>[55]</sup>	An anatomical configuration of the teeth is clearly observed in the CT.
Trope et al. <sup>[56]</sup>	A cyst can be differentiated from the periapical granuloma by a CT because of the marked difference in density.

Cone-beam volumetric tomography (CBVT) or cone-beam computed tomography (CBCT) has been specifically designed to produce undistorted three-dimensional information of the maxillofacial skeleton as well as three-dimensional images of the teeth and their surrounding tissues. This is usually achieved with a substantially lower radiation dose that is very effective, compared to conventional computed tomography (CT).<sup>[58]</sup>

Cone-beam computed tomography (CBCT) uses a cone-shaped beam instead of the fan-shaped one used by the

regular CT scanners.<sup>[59]</sup> Simon et al., reported that CBCT might provide more accurate diagnostic information than a biopsy and histology, when evaluating large periapical lesions.<sup>[60]</sup>

#### *Applications of cone beam computed tomography in the management of endodontic problems*

Endodontic applications of CBCT are less known and not as thoroughly studied.

Specific endodontic applications of CBCT are being identified as the technology becomes more prevalent. Potential endodontic applications include diagnosis of endodontic pathosis and canal morphology, assessment of pathosis of the non-endodontic origin, evaluation of root fractures and trauma, analysis of external, internal root resorption, and invasive cervical resorption, and pre-surgical planning.<sup>[61]</sup>

Periapical disease may be detected early using CBCT compared to the periapical views, and the true size, extent, nature, and position of periapical and resorptive lesions can be assessed. Root fractures, root canal anatomy, and the true nature of the alveolar bone topography around the teeth may be assessed. The CBCT scans are desirable to assess posterior teeth prior to periapical surgery, as the thickness of the cortical and cancellous bone can be accurately determined, as can the inclination of roots in relation to the surrounding jaw. The relationship of anatomical structures such as the maxillary sinus and inferior dental nerve to the root apices may also be clearly visualized.<sup>[58]</sup>

Uses of CBCT are summarized in Table 6.

Cone beam computed tomography can determine the difference in density between the cystic cavity content and the granulomatous tissue, and is preferred as a choice for noninvasive diagnosis.<sup>[62]</sup>

Cone beam computed tomography allows each root and its surrounding structures to be evaluated. Regions of interest can be compared over time. The pre-surgical application of CBCT is an asset in locating lesions, mandibular canals, and the maxillary antrum [Figure 4].<sup>[61]</sup>

#### *Advantages*

The advantages include increased accuracy, higher resolution, scan time reduction, and lower radiation dose. Elimination of anatomic noise, facilitates the assessment of a number of important features on endodontic diagnosis, treatment, and long-term management.<sup>[61]</sup>

#### *Disadvantages*

With regard to CBCT images, the presence of an intracanal metallic post might lead to equivocated interpretations as a

result of artifact formation. When metallic objects are present in either the tooth of interest or an adjacent one, artifacts can pose difficulties in the analysis of images. In these cases, periapical radiographs are helpful to complement the diagnosis. Distortion of metallic structures due to differential absorption is known as a cupping artifact.<sup>[62]</sup>

Although CBCT technology is efficient in imaging hard tissue, it is not very reliable in the imaging of soft tissue, as a result of the lack of dynamic range of the X-ray detector.

Availability of Cone beam computed tomography is limited to major metropolitan areas at present. Limitations also include medico-legal issues pertaining to the acquisition and interpretation of CBCT data. Various dental applications of CBCT (e.g., oral and maxillofacial surgery) require a large field of view (FOV) to capture all maxillofacial structures within the volume. There is a growing concern among oral and maxillofacial radiologists that dentists without proper training should not perform or interpret CBCT images. Results of selected CBCTs studies are summarized in Table 7.

## CONCLUSION

Imaging technology aids in the diagnosis of endodontic

**Table 6: Uses of CBCT**

Uses of CBCT in endodontics
• Evaluation of root canal anatomy
• Study external and internal macro morphology in three-dimensional reconstruction of the teeth
• Evaluation of root canal preparation
• During root canal obturation
• In re-treatment
• Evaluation of coronal microleakage
• Detection of bone lesions
• Experimental endodontology, where it has proved to be accurate in identifying apical periodontitis <sup>[62]</sup>



**Figure 4:** Cone beam CT image shows a sagittal view of impacted maxillary canine with severe dilaceration (arrow).

**Table 7: Summary of selected CBCTs studies**

Kaya et al. <sup>[63]</sup>	The results of this study support the use of CBCT to measure bone density before and after endodontic treatment.
Bornstein et al. <sup>[64]</sup>	The Schneiderian membrane in the vicinity of roots with apical lesions tends to be significantly thicker when compared to the roots of teeth without apical pathosis.
Kim <sup>[65]</sup>	CBCT with larger FOV is useful in nonsurgical endodontic treatment and gives more information compared to digital periapical radiography.
Suter et al. <sup>[66]</sup>	Limited CBCT scans visualized the expansion of the cysts and the involvement of the neighboring structures in both the cases.
Nurbaksh et al. <sup>[67]</sup>	CBCT imaging revealed lower-than-expected prevalence of mucositis adjacent to teeth with apical periodontitis.
Cymerman et al. <sup>[68]</sup>	CBCT scanning was helpful in evaluating patients presenting with concurrent sinus and dental complaints.
Costa et al. <sup>[69]</sup>	CBCT scanning showed high accuracy in detecting horizontal root fracture.
Abella et al. <sup>[70]</sup>	without a metallic post, however, the presence of a metallic post significantly reduced the specificity and sensitivity.
Janner et al. <sup>[71]</sup>	CBCT imaging is useful in identifying the root canal system and the surrounding structures.
Bauman et al. <sup>[72]</sup>	CBCT scan of the teeth can be useful to determine the endodontic working length in combination with clinical measurements.
Bhuva et al. <sup>[73]</sup>	The reliability of detection of maxillary molar mesiobuccal 2 canals in the CBCT scans increased, as the resolution improved.
Idiyatullin et al. <sup>[74]</sup>	CBCT provides additional relevant information on the location and nature of root-resorptive defects when compared with the conventional radiographs.
Edlund et al. <sup>[75]</sup>	CBCT scans can provide the identification of changes in the maxillary sinus and potential causes of sinusitis.
Kottoor et al. <sup>[76]</sup>	This study reveals the superior diagnostic accuracy of CBCT for the detection of a vertical root fracture.
Shemesh et al. <sup>[77]</sup>	CBCT imaging in endodontically challenging cases can facilitate a better understanding of the complex root canal anatomy.
Yoshioka et al. <sup>[78]</sup>	The risk to misdiagnose strip perforations was high with both CBCT and periapical radiography, but CBCT scans showed a significantly higher sensitivity.
Faitaroni et al. <sup>[79]</sup>	CBCT accurately identified the type of periapical bone defect in persistent lesions, which could not be identified by periapical radiography, the diagnostic information obtained by CBCT was essential for the treatment planning process.
Liang et al. <sup>[80]</sup>	CBCT imaging may provide detailed high resolution images of oral structures, which help to make an initial diagnostic hypothesis and to plan surgery.
Kovisto et al. <sup>[81]</sup>	Treatment outcome, length, density of root fillings, and outcome predictors, as determined with CBCT scans, might not be the same as the corresponding values determined with periapical radiographs.
Bornstein et al. <sup>[82]</sup>	The CBCT scan is an accurate, noninvasive method to evaluate the position of the mandibular canal.
Ozer <sup>[83]</sup>	Limited CBCT is advantageous for treatment planning in mandibular molars, before apical surgery.
Bueno et al. <sup>[84]</sup>	CBCT scans are reliable in detecting simulated vertical root fracture, and 0.2 mm voxel was the best protocol, considering the lower x-ray exposure and good diagnostic performance.
Loannidis et al. <sup>[85]</sup>	CBCT images reveal an abnormality that is unable to be detected in a conventional periapical radiograph. A map-reading approach reduces problems related to detection of root perforations near metallic artifacts.
Blattner et al. <sup>[86]</sup>	CBCT images provide a precise description of the anatomy of seven maxillary and mandibular molars with single roots and single canals.
Le et al. <sup>[87]</sup>	CBCT scanning is a reliable method to detect the mesiobuccal (MB)2 canal, when compared to the gold standard of the physical sectioning of the specimen.
Fan et al. <sup>[88]</sup>	CBCT images helped in accurate diagnosis and management of unusual root canal morphology in mandibular first molar.
Patel et al. <sup>[89]</sup>	CBCT images combined with careful exploration may provide an effective way for identifying the nature of the canal system and enhancing debridement in these complex canal anatomies.
Rawi et al. <sup>[90]</sup>	CBCT was effective and reliable in detecting the presence of resorptive lesions. CBCT's superior diagnostic accuracy also resulted in an increased likelihood of their correct management.
	CBCT provided accurate 3D reconstructions of the teeth that could be used for diagnosis, treatment planning, and simulation.

pathosis and canal morphology, assessing root and alveolar fractures, in the analysis of resorptive lesions, identification of the pathosis of non-endodontic origin, and pre-surgical assessment before root-end surgery. When compared with CT, CBCT has increased accuracy, higher resolution, reduced scan time, a reduction in radiation dose, and reduced cost for the patient. As compared with conventional periapical radiography, CBCT eliminates the superimposition of the surrounding structures, providing additional, clinically relevant information. The drawbacks of CBCT include limited availability, significant capital investment, and medico-legal considerations. As the CBCT technology evolves, clinicians will be able to adopt 3-D imaging into their diagnostic repertoire. As accurate diagnostic information leads to better clinical outcomes,

CBCT might prove to be an invaluable tool in the modern dental practice.

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