

# The Role of Digital Technology in Endodontic Diagnosis

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## ABSTRACT

The use of digital technology in endodontic diagnosis has revolutionized the field, improving precision and efficiency in the diagnosis, treatment, and follow-up care of endodontic conditions. This article reviews significant digital breakthroughs, which includes digital radiography, cone-beam computed tomography (CBCT), optical coherence tomography (OCT), and electronic apex locators (EAL). These technologies provide substantial enhancements in the quality of images, accuracy of diagnoses, and overall results for patients. CBCT has shown promising efficacy in detecting complicated root canal anatomies and periapical diseases, offering a clear visualization of the tooth anatomy and adjacent tissues. Optical coherence tomography (OCT) and electronic apex locators (EAL) are important tools for non-invasive diagnostics and accurate determination of root canal length. Moreover, the integration of artificial intelligence (AI) in endodontics has shown potentials in assisting dentists by providing intricate data processing and improves diagnostic capacities. Despite these progressions, there are obstacles such as exorbitant expenses, the requirement for comprehensive instruction, and constraints in imaging specific oral structures endure. Potential future developments encompass continued progress in artificial intelligence (AI) and machine learning, augmented reality (AR), and customized treatment strategies. This analysis highlights the significant advantages of digital technology in endodontic practice and the possibility of continuous advancements to revolutionize the sector.

## KEYWORDS

Endodontic diagnosis; Digital radiography; Cone-Beam Computed Tomography (CBCT); Digital technology; Optical Coherence Tomography (OCT); Electronic Apex Locators (EAL); Artificial Intelligence (AI); Dental innovations

## 1 Introduction

### 1.1 Definition and Importance of Endodontics

Endodontics is a branch of dentistry related to the diagnosis, treatment and prevention of the dental pulp and the surrounding tissues, which is important in saving teeth that would require extraction due to severe decay or infection. Root canal treatment (RCT) and endodontic microsurgery (EMC) are common types of endodontic treatments. Common endodontic surgeries include root-end surgery, crown and root resections, surgical perforation repair and intentional replantation. For both immature teeth with an open apex and mature permanent teeth, the main objective of traditional endodontic treatment is the prevention and/or treatment of apical periodontitis. In addition to these, maintaining pulp vitality and frequently promoting additional root growth are the other goals of endodontic treatment of young teeth. For both mature and immature teeth, reliable criteria for outcome assessment are crucial in determining any treatment success measure.

### 1.2 Integration of Digital Technology

The advancements of digital technology is significantly beneficial to the field. With the use of key advancements including digital radiography, cone-beam computed tomography (CBCT), and advanced imaging techniques like optical coherence tomography (OCT), are examples of the use of digital navigation therapy in the field to help with follow-up care, diagnosis, and treatment <sup>[2]</sup>. The main objective of this review is to introduce the digital tools and innovations in endodontic practice, which enhances precision and efficiency.

## 2 Digital Radiography

### 2.1 Introduction to Digital Radiography

Traditional radiography has long been a cornerstone of medical diagnosis. Since the last decade, periapical radiographs are most commonly used in endodontics, which radiograph films have to be exposed under radiation, and immersed in chemicals to obtain an image in order to aid endodontic diagnosis. The invention of digital radiography provides advantages over tradition radiography, including reduced radiation exposure, enhanced image quality, and immediate image availability. Technologies like cone-beam computed tomography (CBCT) offer three-dimensional (3D) imaging, which provides a more comprehensive view of the tooth structure and surrounding tissues.

### 2.2 Applications in Endodontics

Digital radiographs provide high resolution images that assist in detecting periapical lesions, assessing root canal anatomy and planning treatment with greater accuracy. Cone-beam computed tomography (CBCT) is a commonly used technology in the endodontic field, which has been proved to have an increased detection in periapical lesions by 62%,

comparing to X-ray examinations. The capabilities of 3D imaging also allows a more comprehensive view of tooth structures and surrounding tissues.

### **3 Cone-Beam Computed Tomography (CBCT)**

#### **3.1 Role in Diagnosis and Treatment Planning**

Cone-Beam Computed Tomography (CBCT) is an important turning point for endodontics, providing 3D imaging in intraoral radiography, which enhances the understanding of complex root canal systems, detect fractures and locate calcified canals. The mechanism of CBCT includes an X-ray source and detector in conjunction with a rotating arm and a cone-shaped ionizing radiation source to acquire images. Hundreds of planar projection images are taken from the field of view (FOV) in an arc of at least 180° during the exposure sequence, rotating 180-360° around the patient's head. The process generally takes around 10 to 40 seconds, and is a cost-effective and efficient way of diagnosis and more effective treatment planning, which is a golden standard of care according to many experts in the field. There are different classifications of CBCT, according to the positioning of the patient during imaging taking, scan volume and functions. The positioning allows the scanning process to be conducted under three possible positions: sitting, standing or supine. The dimensions of the FOV also varies, which is dependent on the dimensions and form of the detector, the geometry of the beam projection, and the beam collimation capability. Appropriate field size limitation is important for the imaging of different patients' cases to obtain a good FOV, the use of units include localized region (approximately 5 cm or less), single arch (5 cm to 7 cm), inter-arch (7 cm to 10 cm), maxillofacial (10 cm to 15 cm) and craniofacial (greater than 15 cm).

#### **3.2 Clinical Applications**

##### **3.2.1 Preoperative Assessment**

CBCT is effective in the assessment of surgical endodontic treatment, diagnosing challenging cases and guiding successful treatments. CBCT can identify complex root canal anatomies, which is essential information for endodontic treatment. For example, the prevalence of a second mesiobuccal canal (MB2) in maxillary first molars differs from 69% -93%, depending on method of study [6][7]. The identification of MB2 in maxillary molars is challenging due to anatomical complexity, variation of location and morphology. Conventional radiographic techniques can only detect up to 55% of these configurations, but the detection rates of CBCT ranges from 60% to 93.3%, according to the increasing resolution. CBCT has capabilities to detect common pathological conditions of the teeth are the inflammatory lesions of the pulp and periapical areas, and is proved to be effective in diagnosing apical periodontitis, which significantly increases the number of detected lesions compared to conventional radiographs, Patel et al conducted an experiment which ex vivo models which has 2 mm diameter defects placed in the cancellous bone at the apices of 10 first molar teeth on six partially dentate intact human dry mandibles, the detection rate of CBCT is 100%, and 24.8% for intraoral radiography.

CBCT has been proved to be effective in assessing traumatic root injuries and diagnosing external and internal root resorption. CBCT has capabilities to detect early external root resorption, which is crucial as late diagnosis and treatment can result in hard tissue damage. Conventional radiography has limitations which makes it difficult to differentiate external cervical resorption (ECR) and internal resorption. CBCT is utilized to assessing small lesions, localizing, differentiate types of resorption and determining prognosis.

While root fractures are less common than fractures of the crown and occur in only 7% or fewer of dental injuries, they are difficult to diagnose accurately using conventional radiography. Numerous authors have illustrated the usefulness and importance of CBCT in the diagnosis and management in specific aspects of dento-alveolar trauma, especially root fractures, luxation and/or displacement, and alveolar fracture. There is a higher accuracy for CBCT (0.86) scans than periapical radiographs (0.66) for detecting vertical root fractures (VRT) which was slightly reduced by the presence of opaque obturation material. Bernardes et al. found out that CBCT was able to detect fractures in 18 (90%) of patients whereas conventional periapicals could only detect fractures 6 to 8 of the cases (30% to 40%) and indicated that CBCT was an excellent supplement to conventional radiography in the diagnosis of root fractures.

##### **3.2.2 Postoperative Assessment**

CBCT is important in monitoring the healing process of apical lesions, Kang S. et al. conducted a study to evaluate the effectiveness of CBCT in monitoring one-year radiographic healing after endodontic microsurgery, which CBCT scans demonstrates a lower healing tendency than periapical radiography. As adequacy of root canal obturation is an important determinant of endodontic success, it might be considered that CBCT is also used in the initial and subsequent monitoring of the integrity of root canal fillings.

### **4 Optical Coherence Tomography**

Optical coherence tomography (OCT) is a relatively new and emerging imaging modality in endodontics. Optical coherence tomography (OCT) is a non-invasive imaging technology that can provide high-resolution microscopic images

for diagnostic purposes. The device measures the time delay and intensity of light that is backscattered and reflected from tissues, enabling tomographic imaging of their internal structures. OCT provides real-time imaging of tissues in situ circumventing the need for invasive techniques such as biopsy followed by histology or the need for X-rays. The mechanisms of OCT involves the use of infrared light from a source with a short coherence length. The light waves capture high-resolution cross-sectional images of dental tissues, which can achieve 10 $\mu$ m. [9] Two or three-dimensional, high resolution images of dental tissues can be obtained, providing real-time, non-invasive visualization. OCT can be used for assessing the integrity of the dental pulp and detecting early signs of pulpitis or necrosis. OCT imaging demonstrated capabilities for applications from the occlusal surface, which is proved to be suitable for the analysis of the anatomy and cleanliness of root canal walls, and effective in the diagnosis of vertical root fractures. Although still in nascent stages, OCT shows promising capabilities in improving diagnostic accuracy and guiding minimally invasive treatments.

## 5 Electronic Apex Locators (EAL)

Electronic Apex Locators (EAL) is a type of new, but significantly important technology for endodontic diagnosis, which aids to measure the working length of root canals. EAL references the resistance between periodontal ligament and the oral mucosa, which has a constant of 6.0 k $\Omega$ , in any part of the periodontium. EAL conducts an electrical circuit, which connects one side of the apex's locator's circuit to the oral mucosa with a lip clip and other side to a file, which is then inserted into the root canal and moved apically until the apex of its tip makes contact with periodontal tissue, with the flow of current the precise location of the instrument within the tooth is established, and electrical characteristics of the tooth structure are measured. EALs has 90% accuracy in determining canal length, it still has limitations. Regarding the relative accuracy of radiographic and electronic measurements of working length, it is optimal for EALs to act as an adjuvant with radiography to enhance diagnostic reliability.

## 6 Diagnostic Software and Artificial Intelligence (AI)

Artificial Intelligence (AI) has become a significant cornerstone to endodontic diagnosis through AI-based image analysis. Convolutional neural networks (CNN) and artificial neural networks (ANN) are AI models used in dentistry, and in endodontics, CNN belongs to the neuronal network (NN) category, which endodontics use it for the detection of working length, detect vertical root fractures and evaluate root morphology. Convolutional, pooling, activation, batch normalization, dropout, and fully connected layers are among the layers in CNNs that contribute to the network's capacity to extract complex data and generate accurate predictions. With the combination of the use of these neural network systems, and the accuracy in performing these endodontic tasks can reaches up to 90%.

## 7 Advantages of Digital Technology in Endodontic Diagnosis

There are a lot of benefits in the integration of digital technology in endodontic diagnosis. Among the biggest benefits are improved diagnostic precision and early pathology identification. With the use of digital technologies, exact problem diagnosis is made possible by detailed, high-resolution photographs, which improves treatment planning. Higher diagnostic precision also means better treatment results and a lower chance of encountering complications. Time savings and efficiency are two further advantages of digital technology. Film processing is not necessary with digital radiographs and CBCT scans, which results in faster patient wait times. Enhanced workflow integration reduces clinical practice costs and boosts productivity by streamlining the process from diagnosis to treatment. Digital technology utilization also improves patient experience and satisfaction. Reduced radiation exposure, quicker diagnosis times, and minimally invasive procedures made possible by advanced imaging are all beneficial to patients.

## 8 Challenges and Limitations

Despite many benefits, the adoption of digital technology in endodontic diagnosis faces several challenges. Technological limitations and reliability are the main challenges for AI in endodontics, as large data sets are required for AI to learn, validate, and test algorithms. Training data annotation and labeling take a lot of time and work, especially if CBCT data are being evaluated. The lack of a medical imaging archive from research institutions leads to limited data availability, which may lead to biases, and diagnostic accuracy. Another important problem is that AI in endodontics still lack clinical proof, which numerous clinical trials should be conducted to provide evidences that AI is consistent and accurate for medical use, and ethics should also be implemented and evaluated.

The major limitations of CBCT includes beam hardening when encountering high-density structures such as the enamel, which scattered radiation limits imaging of soft tissues by lowering contrast. Patients are required to exert minimal movement during scans that takes around 15-20 seconds. CBCT also emits radiation that is equal to or even slightly higher than traditional imaging, therefore it should not be used frequently.

## 9 Future Directions and Innovations

The future of digital technology in diagnosing endodontic conditions holds great promise, as continuous developments have the potential to revolutionize the field. Advancements in artificial intelligence (AI) and machine learning will improve diagnostic capabilities, leading to more precise and individualized treatment approaches. Advanced imaging techniques, such as enhanced OCT systems, will provide higher resolution and improved accuracy in diagnosis.

The integration of augmented reality (AR), which is an interactive experience in which computer-generated content is combined with and added to the physical world. In endodontics, dynamic guided navigation approaches are how AI and AR are associated. In order to track the position of a tool or its user and provide real-time orientation feedback, computer vision and machine learning algorithms receive input from imaging sensors used in dynamic navigation or AR headset approaches. The retreatment of fiber posts, guided root-end resection in endodontic microsurgery, and the location of calcified canals have all been accomplished with the use of three-dimensional positional monitoring that permits dynamic navigation. The advancements in reinforcement learning can also lead to innovations in robotics that can possibly contribute to the field.

## 10 Conclusion

In summary, digital technology has greatly improved the diagnosis of endodontic conditions, resulting in greater precision, productivity, and patient results. Advancements in artificial intelligence, imaging techniques, and robots will further stimulate progress in endodontics. Therefore, dental practitioners aiming to deliver the highest level of treatment in a more digital environment must use these technologies. Although computerized diagnostic technologies have downsides such as high costs and training requirements, their benefits are significant.

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