



# International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

**Operating Publisher**  
**SciFormat Publishing Inc.**  
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,  
Calgary, Alberta, T3E0A7,  
Canada  
+15878858911  
editorial-office@sciformat.ca

---

## ARTICLE TITLE

THE ROLE OF CONE-BEAM COMPUTED TOMOGRAPHY IN THE  
DIAGNOSIS AND TREATMENT PLANNING OF COMPLEX ROOT  
CANAL ANATOMY: A NARRATIVE REVIEW

---

## DOI

[https://doi.org/10.31435/ijitss.3\(51\).2026.6537](https://doi.org/10.31435/ijitss.3(51).2026.6537)

---

## RECEIVED

28 July 2026

---

## ACCEPTED

18 September 2026

---

## PUBLISHED

28 September 2026

---

## LICENSE



The article is licensed under a **Creative Commons Attribution 4.0 International License**.

---

© The author(s) 2026.

This article is published as open access under the Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

# THE ROLE OF CONE-BEAM COMPUTED TOMOGRAPHY IN THE DIAGNOSIS AND TREATMENT PLANNING OF COMPLEX ROOT CANAL ANATOMY: A NARRATIVE REVIEW

**Ewa Jurkowska** (Corresponding Author, Email: ewajurkowska@onet.eu)  
Pomeranian Medical University, Szczecin, Poland  
ORCID ID: 0009-0005-7547-4192

**Zofia Wiśniewska**  
Pomeranian Medical University, Szczecin, Poland  
ORCID ID: 0009-0005-7658-094X

---

## ABSTRACT

Cone-beam computed tomography (CBCT) has become an increasingly important imaging modality in contemporary endodontics, particularly in cases involving complex root canal anatomy and diagnostic challenges that cannot be adequately resolved using conventional two-dimensional radiography. The three-dimensional nature of CBCT imaging allows detailed assessment of root and canal morphology, identification of additional canals, detection of periapical pathology, evaluation of root resorption, and assessment of complex anatomical variations. Its application may therefore contribute to more accurate diagnosis and improved treatment planning in selected endodontic cases.

The aim of this narrative review is to critically evaluate the current role of CBCT in the diagnosis and treatment planning of complex root canal anatomy, with particular emphasis on anatomical assessment, identification of additional root canals, detection of periapical lesions, diagnosis of root resorption and vertical root fractures, and the influence of CBCT findings on clinical decision-making. The review also discusses important technical factors affecting diagnostic performance, including voxel size, field of view, image resolution, and metal-related artefacts.

Current evidence indicates that CBCT provides greater diagnostic information than conventional periapical radiography in several complex endodontic situations. Its ability to visualize anatomical structures in three dimensions may improve detection of additional canals and facilitate treatment planning in teeth with unusual or complicated root canal morphology. CBCT also demonstrates considerable diagnostic value in the assessment of periapical pathology, external root resorption, and suspected vertical root fractures. However, diagnostic accuracy may be affected by image artefacts, voxel size, anatomical complexity, and the presence of intracanal or restorative materials.

Despite its diagnostic advantages, CBCT should not be considered a routine replacement for conventional radiography. Its use should be justified on an individual patient basis, particularly when the additional three-dimensional information is expected to influence diagnosis, treatment planning, or prognosis. Appropriate selection of field of view and voxel size is essential to obtain sufficient diagnostic information while minimizing radiation exposure.

CBCT represents a valuable adjunct to conventional endodontic imaging and has the potential to significantly improve the diagnosis and management of complex root canal anatomy. Its greatest clinical value lies in carefully selected cases where three-dimensional information provides clinically relevant information that cannot be obtained adequately through conventional imaging techniques.

---

## KEYWORDS

Cone-beam Computed Tomography, CBCT, Endodontics, Root Canal Anatomy, Endodontic Diagnosis, Treatment Planning, Periapical Lesions, Root Resorption, Vertical Root Fracture, Three-dimensional Imaging

---

## CITATION

Jurkowska, E., & Wiśniewska, Z. (2026). The role of cone-beam computed tomography in the diagnosis and treatment planning of complex root canal anatomy: A narrative review. *International Journal of Innovative Technologies in Social Science*, 3(51). [https://doi.org/10.31435/ijitss.3\(51\).2026.6537](https://doi.org/10.31435/ijitss.3(51).2026.6537)

---

## COPYRIGHT

© **The author(s) 2026**. This article is published as open access under the Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

---

## 1. Introduction

Endodontic treatment is fundamentally dependent on accurate diagnosis and adequate knowledge of root canal anatomy. The internal anatomy of the root canal system is highly complex and may demonstrate substantial variations in the number, configuration, curvature, and interconnections of root canals. Additional canals, accessory canals, isthmuses, apical ramifications, and complex root morphology may remain undetected during conventional clinical and radiographic examination, potentially increasing the risk of missed anatomy and inadequate treatment [1,2].

Conventional periapical radiography remains an essential component of endodontic diagnosis and treatment planning. However, its two-dimensional nature limits the visualization of three-dimensional anatomical structures and may result in superimposition of roots, canals, and surrounding anatomical structures. These limitations become particularly relevant when clinicians encounter complex root canal morphology, suspected additional canals, extensive periapical pathology, root resorption, or suspected root fractures [1,3].

Cone-beam computed tomography (CBCT) has significantly expanded the diagnostic capabilities available to endodontists by providing three-dimensional images of the dentoalveolar region. Unlike conventional radiography, CBCT allows anatomical structures to be evaluated in axial, sagittal, and coronal planes, providing additional information regarding root morphology, canal configuration, cortical bone, and periapical tissues. This three-dimensional approach can facilitate identification of anatomical variations that may not be adequately visualized using conventional two-dimensional imaging [1,2].

The clinical value of CBCT is particularly evident when the complexity of root canal anatomy creates diagnostic or treatment-planning challenges. Additional canals are among the most important anatomical variations that may contribute to unsuccessful endodontic treatment when they remain untreated. A systematic review and meta-analysis evaluating the diagnostic accuracy of CBCT for detecting additional canals demonstrated high diagnostic performance, supporting its usefulness in selected cases where the presence of an additional canal is suspected [7]. Similarly, clinical investigations have demonstrated that CBCT can improve the ability of clinicians to identify the second mesiobuccal canal (MB2) in maxillary molars, an anatomical feature that is frequently difficult to detect using conventional radiographic methods [8].

Beyond assessment of root canal anatomy, CBCT has become increasingly relevant to the diagnosis of periapical disease. Periapical lesions may not always be visible on conventional radiographs, particularly when lesions are small or when their anatomical relationship with surrounding structures is complex. Three-dimensional imaging can provide additional information regarding the presence, location, and extent of periapical bone changes. Systematic reviews have demonstrated that CBCT may provide higher diagnostic accuracy for the detection of apical periodontitis than conventional periapical radiography, although its diagnostic performance depends on imaging parameters and lesion characteristics [9,10].

CBCT may also play an important role in the assessment of root resorption. External root resorption can be difficult to distinguish from other radiolucent lesions using conventional two-dimensional radiographs because of anatomical superimposition. The three-dimensional visualization provided by CBCT allows clinicians to determine the location and extent of resorptive defects more accurately and may assist in determining whether the lesion is amenable to conservative treatment or requires more extensive intervention [11].

Another important application is the evaluation of suspected vertical root fractures. Diagnosis of vertical root fracture can be particularly challenging because clinical signs and conventional radiographic findings may be nonspecific. CBCT can provide additional information regarding fracture-associated bone defects and root morphology, although its diagnostic accuracy is affected by fracture orientation, fracture width, root filling materials, posts, and other high-density structures that may generate artefacts [12–14].

The increasing use of CBCT in endodontics has also raised important questions regarding the optimal imaging protocol. Image quality and diagnostic performance are influenced by parameters such as voxel size, field of view, exposure settings, and reconstruction algorithms. Smaller voxel sizes generally provide higher spatial resolution and may improve visualization of fine anatomical structures; however, they may also be associated with increased radiation exposure and larger image datasets. Recent systematic evidence indicates that voxel size can influence CBCT-based assessment of root canal anatomy, emphasizing the importance of selecting imaging parameters according to the specific diagnostic task rather than routinely using the highest available resolution [6].

Metal-related artefacts represent another important limitation of CBCT interpretation. Root canal filling materials, metallic posts, crowns, and other high-density structures can produce beam-hardening and streaking artefacts that obscure anatomical structures and potentially reduce diagnostic accuracy. Although metal

artefact reduction algorithms may improve image quality in some situations, their effectiveness varies according to the type and location of the material and the specific CBCT system used [13].

Importantly, the increasing diagnostic capabilities of CBCT do not justify its routine use in every endodontic patient. Radiation exposure, although generally lower than that associated with conventional medical computed tomography, remains an important consideration. Current recommendations emphasize that CBCT should be prescribed only when the expected diagnostic information is likely to influence diagnosis, treatment planning, or prognosis and when conventional imaging does not provide sufficient information [3].

Recent evidence has further demonstrated that CBCT may influence endodontic treatment planning and clinicians' diagnostic confidence. Systematic reviews indicate that three-dimensional imaging can lead to changes in diagnosis and treatment strategy in selected cases, particularly when complex anatomy or pathology is present. However, the clinical significance of these changes and their effect on long-term treatment outcomes remain areas of ongoing investigation [4,5].

The role of CBCT in contemporary endodontics should therefore be understood as an adjunctive diagnostic technology rather than a universal replacement for conventional radiography. Its greatest value is observed in carefully selected cases in which three-dimensional anatomical information can resolve diagnostic uncertainty or directly influence treatment planning. The appropriate use of CBCT requires consideration of the clinical question, anatomical complexity, imaging parameters, radiation dose, and potential diagnostic benefits [1–6].

The aim of this narrative review is to critically evaluate the current role of cone-beam computed tomography in the diagnosis and treatment planning of complex root canal anatomy, with particular emphasis on three-dimensional anatomical assessment, detection of additional root canals, diagnosis of periapical pathology, root resorption and vertical root fractures, as well as the influence of technical imaging parameters and artefacts on diagnostic accuracy.

## 2. Methodology

### 2.1. Review Design

This study was designed as a narrative review addressing the contemporary role of cone-beam computed tomography (CBCT) in endodontic diagnosis and treatment planning, with particular emphasis on cases involving complex root canal anatomy. The review focused on the diagnostic applications of CBCT in the assessment of root canal morphology, identification of additional canals, detection of periapical pathology, evaluation of root resorption, diagnosis of suspected vertical root fractures, and treatment planning in anatomically complex cases [1–5].

The review also considered technical factors that may influence the diagnostic performance of CBCT, including voxel size, field of view, image resolution, and the presence of artefacts associated with intracanal and restorative materials [6,13]. Particular attention was given to evidence evaluating the clinical impact of CBCT on diagnostic confidence and treatment-planning decisions, as these outcomes are more clinically relevant than imaging performance alone [4,5].

### 2.2. Literature Search Strategy

A structured literature search was performed using major biomedical and dental literature databases, including PubMed/MEDLINE, Scopus, and Web of Science. The search strategy focused on publications addressing the diagnostic and clinical applications of CBCT in endodontics.

The following keywords and combinations of terms were considered: *cone-beam computed tomography*, *CBCT*, *endodontics*, *root canal anatomy*, *root canal morphology*, *additional canals*, *MB2*, *apical periodontitis*, *periapical lesions*, *external root resorption*, *vertical root fracture*, *endodontic treatment planning*, *voxel size*, *metal artefacts*, and *diagnostic accuracy*.

Boolean operators such as AND and OR were used to combine search terms. Additional relevant publications were identified through examination of the reference lists of selected articles and major review papers. Particular emphasis was placed on systematic reviews, meta-analyses, clinical investigations, evidence-based recommendations, and contemporary reviews published in peer-reviewed endodontic and dental journals [1–5,7–15].

### 2.3. Eligibility Criteria

Publications were considered relevant when they addressed one or more of the following aspects of CBCT use in endodontics:

1. three-dimensional assessment of root and root canal anatomy;
2. identification of additional root canals;
3. detection of complex canal configurations;
4. diagnosis of apical periodontitis and periapical lesions;
5. assessment of external root resorption;
6. diagnosis of vertical root fractures;
7. influence of CBCT on endodontic treatment planning;
8. diagnostic confidence and changes in clinical decision-making;
9. influence of voxel size and other imaging parameters;
10. artefacts associated with intracanal and restorative materials;
11. comparison of CBCT with conventional periapical radiography.

Priority was given to systematic reviews and meta-analyses because they provide higher-level evidence regarding diagnostic accuracy and clinical applications [4,5,7,9–15]. Clinical and observational studies were also considered when they provided direct evidence regarding the practical value of CBCT in endodontic diagnosis and treatment planning [8].

Publications were excluded when they were unrelated to endodontic imaging, did not provide clinically relevant information regarding CBCT applications, or lacked sufficient methodological information to allow meaningful interpretation. Case reports, editorials, conference abstracts, and publications without relevant diagnostic or clinical outcomes were not considered among the principal sources of evidence.

### 2.4. Data Extraction and Qualitative Synthesis

The selected literature was qualitatively analyzed according to several predefined categories. For each publication, attention was given to the clinical or diagnostic question investigated, CBCT imaging parameters, reference standard where applicable, anatomical region examined, diagnostic outcome, and principal conclusions.

The primary focus was the ability of CBCT to provide additional diagnostic information regarding complex root canal anatomy. This included identification of additional canals, assessment of root morphology, and visualization of anatomical structures that may be obscured or superimposed on conventional two-dimensional radiographs [1,2,7,8].

Secondary outcomes included diagnostic performance for periapical lesions, external root resorption, and vertical root fractures. Comparative evidence between CBCT and conventional radiography was considered particularly relevant when assessing whether three-dimensional imaging provides clinically meaningful diagnostic advantages [9–12,14].

Technical factors were evaluated separately because CBCT diagnostic performance is not determined solely by the use of three-dimensional imaging. Voxel size, field of view, spatial resolution, and artefacts may substantially influence the visibility of small anatomical structures and pathological findings. Recent evidence concerning voxel size was therefore incorporated to assess the relationship between imaging resolution and the reliability of root canal anatomy assessment [6]. The influence of metal artefact reduction techniques was also considered because intracanal materials and metallic restorations can significantly affect image interpretation [13].

Finally, studies evaluating the influence of CBCT on treatment planning and clinical decision-making were analyzed separately. This distinction is important because improved image quality or diagnostic accuracy does not necessarily translate into a clinically meaningful change in treatment. Evidence demonstrating changes in diagnosis, treatment selection, or clinician confidence was therefore considered particularly relevant to the clinical interpretation of CBCT [4,5].

### 2.5. Methodological Considerations

The present study represents a narrative review and was not designed as a systematic review or meta-analysis. Consequently, the objective was to provide a critical qualitative synthesis of the available evidence rather than calculate pooled estimates across all identified studies.

The interpretation of CBCT literature requires consideration of substantial methodological heterogeneity. Differences between studies may include CBCT devices, voxel sizes, fields of view, exposure

parameters, image reconstruction methods, reference standards, anatomical regions, and diagnostic criteria. Such differences can substantially influence reported diagnostic accuracy and make direct numerical comparison between individual studies difficult [1,6,9,13].

Furthermore, the diagnostic performance demonstrated under experimental conditions may not necessarily correspond to the clinical performance of CBCT in routine endodontic practice. Patient movement, metallic restorations, root filling materials, anatomical complexity, and variations in image interpretation may influence the final diagnostic outcome. For this reason, the present review places particular emphasis on evidence addressing the clinical consequences of CBCT findings, rather than relying exclusively on technical measures of image quality or diagnostic accuracy [4,5,13].

The selected evidence was subsequently synthesized into the following major areas: CBCT assessment of complex root canal anatomy, detection of additional canals, diagnosis of periapical pathology, evaluation of root resorption and vertical root fractures, influence of imaging parameters and artefacts, and implications for endodontic treatment planning.

### **3. CBCT in the Assessment of Complex Root Canal Anatomy**

The complex three-dimensional morphology of the root canal system represents one of the principal challenges in endodontic diagnosis and treatment. Root canals may exhibit multiple configurations, accessory canals, isthmuses, apical ramifications, abrupt curvatures, and additional roots that cannot always be adequately identified using conventional two-dimensional radiography. Accurate preoperative assessment of this anatomy is particularly important because failure to identify additional canals or unusual anatomical configurations may result in incomplete debridement and persistent intracanal infection [1,2].

Conventional periapical radiography provides valuable information regarding the number, length, and general curvature of roots; however, anatomical structures are compressed into a two-dimensional image. Superimposition of roots and surrounding anatomical structures can consequently obscure important details of the root canal system. CBCT overcomes some of these limitations by generating three-dimensional datasets that can be examined in axial, sagittal, and coronal planes. This allows the clinician to assess root morphology and canal configuration from multiple perspectives before and during treatment [1–3].

The clinical relevance of CBCT is particularly evident in teeth with suspected complex anatomy. Conditions such as C-shaped canals, dens invaginatus, taurodontism, fused or geminated teeth, additional roots, and unusually curved canals may present significant challenges during access preparation and instrumentation. CBCT can provide information regarding the number and trajectory of canals, the location of canal orifices, the relationship between individual canals, the presence of isthmuses, and the thickness of surrounding dentin. This information may assist the clinician in designing a more conservative and anatomically appropriate access cavity while reducing the risk of unnecessary removal of tooth structure [1,2].

One of the most clinically relevant applications of CBCT is the detection of additional root canals. Missed canals are an important cause of persistent endodontic infection and may contribute to the development or persistence of apical periodontitis. A systematic review and meta-analysis evaluating the diagnostic accuracy of CBCT for detection of second canals reported pooled sensitivity and specificity of approximately 94% and 93.1%, respectively. For the second mesiobuccal canal (MB2), sensitivity was reported to be approximately 96.6%, demonstrating the considerable diagnostic potential of CBCT for identifying additional canal anatomy [7].

The maxillary first molar represents a particularly important clinical example. The mesiobuccal root frequently contains two canals, with the MB2 canal often located in close proximity to the main mesiobuccal canal. Its orifice may be concealed by dentin or difficult to identify because of calcification and anatomical variation. CBCT can demonstrate the presence and trajectory of an MB2 canal and may therefore provide useful information before or during treatment [7,8].

However, the diagnostic value of CBCT should not be interpreted as absolute. A prospective clinical study evaluating the use of CBCT for locating MB2 canals in maxillary molars demonstrated that CBCT did not allow direct visualization of every additional canal. In that study, MB2 was located during initial access in 70% of teeth, while CBCT combined with selective troughing enabled identification of additional MB2 canals in a proportion of the remaining cases. Overall, the combination of clinical examination, magnification, selective troughing, and CBCT achieved a substantially higher detection rate than any single diagnostic approach [8]. This finding highlights an important principle: CBCT should complement rather than replace careful clinical examination and magnification.

Population-based CBCT studies further demonstrate substantial variation in root canal anatomy. For example, retrospective assessment of maxillary molars has shown a high prevalence of MB2 canals in maxillary first molars, while a considerable proportion of these canals remained untreated in previously root-filled teeth. The presence of unfilled MB2 canals was associated with periapical radiolucency in a substantial proportion of affected teeth, emphasizing the clinical importance of accurate anatomical assessment [7,8].

CBCT is also useful for evaluating the spatial relationship between canals and surrounding dentinal structures. Preoperative identification of areas with reduced dentin thickness may influence the design of the access cavity and instrumentation strategy. This is particularly relevant in teeth with severe curvatures or unusual root morphology, where aggressive instrumentation may increase the risk of strip perforation or excessive weakening of the root. Three-dimensional visualization can therefore contribute not only to detection of anatomy but also to more conservative treatment planning [1,2].

The diagnostic performance of CBCT is strongly influenced by imaging parameters. Voxel size is particularly important when evaluating small anatomical structures such as accessory canals or narrow canal orifices. Recent systematic evidence indicates that voxel size can affect CBCT-based assessment of root canal anatomy, although the optimal resolution depends on the specific diagnostic task. Smaller voxel sizes may improve spatial resolution, but their use should be balanced against radiation exposure and other technical considerations [6].

Field of view (FOV) is another important consideration. A limited FOV may provide higher spatial resolution and reduce radiation exposure compared with larger-volume scans. For endodontic applications, a limited FOV focused on the tooth or region of interest is generally preferable when it provides sufficient diagnostic information. The selection of FOV should therefore be based on the clinical question rather than on routine acquisition of unnecessarily large volumes [2,3].

The interpretation of complex root canal anatomy also depends on the clinician's ability to recognize anatomical variations across multiple imaging planes. Axial reconstructions may be particularly useful for identifying the number and configuration of canals, whereas sagittal and coronal views can provide additional information regarding canal curvature and the relationship between canals and external root surfaces. Three-dimensional CBCT assessment should therefore be regarded as a dynamic diagnostic process rather than interpretation of a single reconstructed image [1,2].

Despite its advantages, CBCT cannot visualize every component of the root canal system with equal reliability. Very narrow canals, calcified canals, fine accessory anatomy, and structures affected by artefacts may remain difficult to identify. In addition, diagnostic accuracy can vary depending on voxel size, image quality, canal anatomy, and the reference standard used to determine the true presence of a canal [6,7].

Overall, current evidence supports CBCT as a valuable diagnostic adjunct in cases where complex root canal anatomy is suspected. Its greatest benefit is obtained when three-dimensional information can directly influence access cavity design, canal identification, instrumentation strategy, or the decision to undertake or modify endodontic treatment. CBCT should therefore be integrated with clinical examination, conventional radiography, magnification, and knowledge of expected anatomical patterns rather than used as an isolated diagnostic modality [1–3,7,8].

The assessment of complex anatomy represents only one component of the diagnostic role of CBCT. Its application is also highly relevant to the identification and characterization of periapical pathology, where three-dimensional imaging can reveal lesions that may be difficult or impossible to detect on conventional radiographs.

#### **4. CBCT in the Diagnosis of Periapical Pathology**

The diagnosis of apical periodontitis is an essential component of endodontic treatment planning and follow-up. Conventional periapical radiography remains the primary imaging modality in routine endodontic practice; however, its two-dimensional nature limits the detection and characterization of periapical pathology. The presence of anatomical superimposition, variations in bone density, and the three-dimensional distribution of inflammatory lesions may result in lesions that are not readily apparent on conventional radiographs. CBCT provides an alternative approach by allowing visualization of periapical structures in three dimensions and may therefore increase the diagnostic sensitivity for apical pathology [1,2,9,10].

One of the principal advantages of CBCT is its ability to detect periapical bone changes before they become clearly visible on conventional radiographs. A periapical lesion may initially develop within cancellous bone without producing sufficient cortical alteration to generate a detectable radiolucency on a two-

dimensional radiograph. CBCT can visualize changes in the trabecular and cortical bone architecture from multiple planes, potentially allowing earlier identification of periapical inflammatory changes [9,10].

Systematic reviews have demonstrated that CBCT generally provides greater diagnostic accuracy for the detection of apical periodontitis than conventional periapical radiography. A systematic review and meta-analysis by Leonardi Dutra et al. reported higher diagnostic performance of CBCT for detecting apical periodontitis compared with conventional radiography [10]. Similarly, a systematic review using a hierarchical diagnostic model demonstrated that CBCT provides clinically relevant additional information when evaluating periapical lesions, although considerable heterogeneity exists among studies regarding imaging parameters, reference standards, and lesion characteristics [9].

The superiority of CBCT is particularly relevant in cases where conventional radiographs provide equivocal findings. A patient may present with persistent symptoms, tenderness to percussion, or other clinical signs suggestive of apical periodontitis despite the absence of a clearly defined periapical radiolucency on conventional imaging. In such situations, CBCT may reveal a lesion that is obscured by anatomical structures or has not yet produced sufficient cortical bone destruction to become radiographically evident [1,9,10].

Three-dimensional imaging also provides additional information regarding the location, extent, and spatial relationship of periapical lesions. Unlike conventional radiography, CBCT can demonstrate whether a lesion is associated with the buccal or palatal/lingual cortical plate and can provide information regarding the relationship between the lesion and adjacent roots, anatomical structures, and cortical bone. This information may be particularly useful when planning endodontic surgery or evaluating lesions in anatomically complex regions [1,2,9].

The diagnostic value of CBCT extends beyond simply identifying whether a periapical lesion is present. Three-dimensional imaging may help distinguish between endodontic and non-endodontic causes of periapical radiolucency by providing information regarding the relationship of the lesion to the root apex and surrounding anatomical structures. Nevertheless, CBCT findings alone cannot reliably establish the histopathological nature of a periapical lesion. A radiolucency identified on CBCT should therefore be interpreted in conjunction with clinical findings, pulp sensibility testing, previous treatment history, and other diagnostic information [1,2].

An important consideration is that greater sensitivity does not necessarily mean that CBCT should replace conventional radiography for routine diagnosis. The increased diagnostic information provided by CBCT must be balanced against radiation exposure, cost, accessibility, and the possibility of identifying incidental findings that may complicate clinical decision-making. Current recommendations therefore support the use of CBCT when conventional imaging does not provide sufficient information to answer a specific clinical question or when the additional information is expected to influence treatment planning [3].

The interpretation of periapical pathology using CBCT is also influenced by imaging parameters. Voxel size and field of view can affect the visualization of small osseous defects and early periapical changes. Although smaller voxels may improve spatial resolution, the relationship between voxel size and diagnostic accuracy is not necessarily linear. Recent systematic evidence indicates that the optimal voxel size depends on the specific diagnostic task and that unnecessarily high-resolution imaging should not be routinely performed when a lower-dose protocol provides sufficient diagnostic information [6].

Another important limitation is the possibility of false-positive findings. CBCT is highly sensitive to subtle changes in bone density, and anatomical structures such as the maxillary sinus, incisive canal, mental foramen, or trabecular variations may occasionally mimic pathological lesions. The interpretation of CBCT therefore requires adequate knowledge of normal anatomical structures and the ability to distinguish pathological changes from normal anatomical variations [1,2,9].

The clinical significance of CBCT-detected lesions also depends on the patient's clinical context. Detection of a small periapical radiolucency that is not visible on conventional radiography may confirm the presence of apical disease, but the finding should not automatically result in more aggressive treatment. Instead, CBCT should provide additional information that supports a comprehensive diagnostic process and helps determine whether intervention, retreatment, monitoring, or further investigation is appropriate [3–5].

CBCT is particularly valuable in previously treated teeth with persistent or recurrent disease. In these cases, conventional radiographs may fail to adequately demonstrate the extent of periapical pathology or its relationship with complex root anatomy. CBCT can simultaneously provide information regarding the quality of previous root canal treatment, untreated canals, periapical bone destruction, and potential procedural complications. This multidimensional information may therefore contribute to a more informed decision regarding nonsurgical retreatment, surgical intervention, or extraction [4,5].

The use of CBCT in endodontic diagnosis should consequently be based on the principle of diagnostic justification. The technology offers clear advantages in detecting and characterizing periapical pathology, particularly when conventional radiography produces uncertain or inconclusive findings. However, its routine use in patients without specific diagnostic indications cannot be justified solely on the basis of its superior image quality [1–3].

Overall, current evidence supports CBCT as a highly valuable adjunct for the diagnosis and assessment of periapical pathology. Its three-dimensional capabilities improve visualization of lesions, provide information regarding their spatial extent, and may reveal pathology that remains undetected on conventional radiographs. Nevertheless, CBCT findings should always be integrated with clinical examination and conventional imaging, with the examination selected according to the individual diagnostic question and the principle of minimizing unnecessary radiation exposure [3,9,10].

## **5. CBCT in the Detection of Root Resorption and Vertical Root Fractures**

Root resorption and vertical root fractures represent two clinically challenging conditions in endodontics because their diagnosis may be difficult using conventional two-dimensional radiography. Both conditions can present with nonspecific clinical symptoms and radiographic findings, while their accurate localization and characterization are essential for determining prognosis and selecting an appropriate treatment strategy. The three-dimensional capabilities of cone-beam computed tomography (CBCT) may provide important additional information in these situations, particularly when conventional radiographic findings are inconclusive [1,2,11,12].

### **5.1. External Root Resorption**

External root resorption is characterized by progressive loss of dental hard tissue originating from the external root surface. Depending on its location and extent, external resorption may be difficult to identify on conventional periapical radiographs because the resorptive defect can be superimposed on the root canal or other anatomical structures. This limitation may result in delayed diagnosis or inaccurate assessment of the size and location of the lesion [1,11].

CBCT provides a significant diagnostic advantage by allowing resorptive defects to be visualized in three dimensions. The clinician can determine the exact location of the defect relative to the root canal, external root surface, and surrounding bone. This information may be particularly important when distinguishing external resorption from internal root resorption, as the two conditions may appear similar on conventional radiographs but require different clinical management strategies [1,11].

A systematic review and meta-analysis comparing CBCT with periapical radiography for the diagnosis of external root resorption demonstrated superior diagnostic performance of CBCT. The ability to visualize the resorptive defect from multiple planes allows clinicians to assess whether the lesion is located on the buccal, palatal, mesial, or distal aspect of the root and to determine its relationship with the root canal [11].

The three-dimensional information provided by CBCT may also influence treatment planning. Small and localized external resorptive defects may be suitable for conservative management when the resorptive process can be accessed and controlled. In contrast, extensive lesions involving a large portion of the root or extending into anatomically inaccessible areas may have a less favorable prognosis. CBCT can therefore contribute not only to diagnosis but also to determining the feasibility and complexity of potential treatment [1,11].

Nevertheless, CBCT should not be considered infallible in the diagnosis of root resorption. Small defects may remain difficult to visualize depending on voxel size, image quality, and the anatomical relationship between the lesion and surrounding structures. The diagnostic performance of CBCT may therefore vary according to the size and location of the resorptive defect and the technical parameters used during image acquisition [6,11].

### **5.2. Vertical Root Fractures**

Vertical root fractures (VRFs) represent another major diagnostic challenge in endodontics. They are particularly common in root-filled teeth and may be associated with persistent symptoms, localized periodontal defects, sinus tract formation, and characteristic patterns of bone loss. However, none of these findings is pathognomonic, and conventional periapical radiographs frequently fail to demonstrate the fracture line directly [12–14].

CBCT has been extensively investigated as a potential diagnostic tool for VRFs because its three-dimensional nature may allow visualization of fracture-associated bone defects and, in selected cases, the fracture itself. Compared with conventional radiography, CBCT may provide additional information regarding the distribution of bone loss around the affected root and the relationship between the fracture and surrounding anatomical structures [12,14].

However, the diagnostic performance of CBCT for VRFs is considerably more complex than its performance in the assessment of root resorption. A systematic review evaluating CBCT in endodontically treated teeth reported substantial variability in sensitivity and specificity between studies and concluded that the available evidence was insufficient to consider CBCT a consistently reliable diagnostic test for VRFs [12].

More recent systematic evidence has similarly demonstrated considerable limitations. A review of CBCT studies involving endodontically treated teeth reported mean sensitivity of approximately 71.5% and specificity of approximately 75.6% when root-filled teeth without intracanal posts were evaluated. In teeth containing intracanal posts, mean sensitivity and specificity were approximately 72.8% and 75.4%, respectively. These findings demonstrate that although CBCT can provide valuable diagnostic information, a negative CBCT examination cannot reliably exclude the presence of a vertical root fracture [12].

One of the principal limitations of CBCT in the diagnosis of VRFs is the presence of high-density intracanal materials. Gutta-percha, metallic posts, crowns, and other restorative materials can generate beam-hardening and streaking artefacts that obscure the root structure and may either conceal a true fracture or produce an apparent fracture line. This limitation is particularly important in previously root-filled teeth, which constitute a substantial proportion of suspected VRF cases [13,14].

Metal artefact reduction (MAR) algorithms have therefore been investigated as a means of improving CBCT-based diagnosis of VRFs. However, systematic evidence suggests that the benefit of MAR is inconsistent and may depend on the type of intracanal material, CBCT device, and image reconstruction protocol. Consequently, activation of a MAR algorithm should not be interpreted as guaranteeing improved diagnostic accuracy in every case [13].

Recent research has further emphasized that metal artefacts generated by gutta-percha and implants can negatively affect VRF detection and that different reconstruction approaches do not necessarily eliminate this problem. This reinforces the importance of interpreting CBCT findings in conjunction with clinical signs and conventional imaging rather than relying exclusively on a suspected fracture line visible on a three-dimensional reconstruction.

The clinical diagnosis of a vertical root fracture should therefore be based on a multimodal diagnostic approach. Findings such as an isolated deep periodontal pocket, localized bone loss, sinus tract, persistent symptoms, and previous endodontic treatment may increase the clinical suspicion of a fracture. CBCT can then provide additional information regarding the distribution of bone loss and the anatomy of the affected root, but the final diagnosis may remain uncertain until direct visualization or surgical exploration is possible [12–14].

This distinction is particularly important because the consequences of an incorrect diagnosis can be substantial. A false-positive diagnosis may result in unnecessary extraction of a potentially restorable tooth, whereas a false-negative diagnosis may lead to inappropriate retreatment of a tooth whose underlying problem is structural rather than infectious. CBCT should therefore be regarded as an important component of the diagnostic process rather than as an independent definitive test [3,12–14].

Overall, CBCT provides considerably more useful three-dimensional information for the assessment of external root resorption than conventional radiography and can substantially improve localization and characterization of resorptive defects. Its role in the diagnosis of vertical root fractures is more limited because of relatively modest diagnostic accuracy and significant susceptibility to artefacts. The clinical value of CBCT is therefore highly dependent on the specific diagnostic question, the presence of intracanal materials, imaging parameters, and integration with clinical findings [11–14].

The distinction between these two applications illustrates an important principle of contemporary CBCT-based endodontic diagnosis: greater anatomical information does not automatically translate into definitive diagnosis. CBCT should instead be used when its three-dimensional information has a reasonable likelihood of changing the diagnostic assessment, treatment strategy, or prognosis of the affected tooth [1–5].

## 6. Influence of CBCT on Endodontic Treatment Planning and Clinical Decision-Making

The primary clinical value of cone-beam computed tomography (CBCT) lies not simply in its ability to produce high-resolution three-dimensional images, but in its potential to provide information that changes diagnosis, treatment planning, or prognosis. In contemporary endodontics, imaging should therefore be considered clinically useful when the additional information obtained from CBCT has the potential to influence patient management. This principle is particularly relevant in complex cases where conventional radiography does not adequately explain the clinical findings or anatomical situation [3–5].

The influence of CBCT on endodontic treatment planning has been investigated in several clinical studies and systematic reviews. A systematic review by Tay et al. demonstrated that CBCT frequently influenced treatment planning, particularly in cases considered to be of high difficulty, previously treated symptomatic teeth, assessment of periapical healing, pre-surgical planning, traumatic injuries, and external cervical resorption. Across the studies included in that review, treatment plans changed in a substantial proportion of cases after CBCT information became available [5]. This finding indicates that CBCT may provide clinically meaningful information beyond that obtained from conventional periapical radiographs.

More recent evidence has further confirmed the impact of CBCT on endodontic decision-making. A 2025 systematic review by Trindade et al., which included 26 studies evaluating changes in diagnosis, treatment planning, and clinician confidence, demonstrated that CBCT influenced clinical decision-making particularly in complex endodontic cases. The effect was especially evident in situations involving complex root canal morphology, external root resorption, and dental trauma [4]. Importantly, the review also found that CBCT information sometimes resulted in more invasive treatment recommendations, including surgical intervention or extraction.

This observation highlights an important distinction between diagnostic information and therapeutic benefit. The availability of additional anatomical information may increase clinicians' confidence in their diagnosis but does not necessarily lead to a more conservative treatment. In some cases, CBCT may reveal a more extensive pathological process or anatomical complication than initially suspected, resulting in a decision to undertake a more complex intervention. Therefore, the clinical impact of CBCT should be assessed not only according to diagnostic accuracy but also according to whether the resulting change in treatment planning improves patient management [4,5].

CBCT can be particularly valuable when evaluating teeth with previously unsuccessful endodontic treatment. Persistent symptoms or periapical pathology after root canal treatment may result from missed canals, inadequate obturation, untreated anatomical variations, procedural complications, persistent infection, or non-endodontic pathology. Conventional radiographs may provide insufficient information to distinguish between these possibilities. CBCT can simultaneously demonstrate untreated canals, the quality and extent of the existing root canal filling, periapical bone changes, root morphology, and potential complications, thereby helping clinicians determine whether nonsurgical retreatment, endodontic surgery, monitoring, or extraction is most appropriate [1,4,5].

The use of CBCT may also be particularly beneficial before endodontic surgery. Three-dimensional imaging can provide information regarding the location and extent of periapical lesions, cortical bone thickness, root morphology, proximity to anatomical structures, and the presence of untreated canals or additional roots. Such information can assist in selecting the surgical approach and identifying potential anatomical risks. Consequently, CBCT may contribute to more predictable preoperative planning in cases where surgical intervention is being considered [2,5].

Another important clinical application is the assessment of traumatic dental injuries. Trauma may result in root fractures, alveolar fractures, root resorption, displacement, or other anatomical changes that are difficult to characterize using conventional radiography. Because CBCT allows visualization in multiple planes, it can provide additional information regarding the extent and location of traumatic injuries and may therefore influence treatment selection and prognosis. The recent systematic review by Trindade et al. identified dental trauma as one of the clinical situations in which CBCT produced particularly substantial improvements in diagnostic assessment and treatment planning [4].

CBCT may also influence clinicians' perception of treatment difficulty. Complex root canal morphology, severe curvature, additional canals, resorption defects, and unusual root anatomy can substantially alter the technical difficulty of endodontic treatment. Three-dimensional visualization allows these characteristics to be identified before treatment begins, potentially facilitating referral of particularly difficult cases to specialists.

Conversely, CBCT may demonstrate anatomy that is more favorable than initially suspected and provide additional confidence in undertaking treatment [1–5].

Nevertheless, increased diagnostic information does not automatically translate into improved treatment outcomes. The evidence regarding the direct effect of CBCT-guided treatment planning on long-term tooth survival and endodontic success remains limited. Most studies evaluate changes in diagnosis or treatment plans rather than patient-centered clinical outcomes. Furthermore, heterogeneity in study design, case selection, imaging protocols, and clinician experience makes it difficult to establish a universal magnitude of benefit associated with CBCT [4,5].

An additional concern is the possibility of overdiagnosis and overtreatment. Because CBCT is capable of revealing subtle anatomical and pathological findings, clinicians may identify abnormalities that would not necessarily have altered the biological course of the disease. The increased availability of three-dimensional information may also lead to more aggressive treatment decisions in uncertain cases. The recent systematic review evidence indicating a tendency toward more invasive treatment after CBCT assessment reinforces the importance of interpreting CBCT findings within the broader clinical context rather than treating every radiographic abnormality as an indication for intervention [4,5].

For this reason, CBCT should be incorporated into endodontic decision-making according to a clearly defined clinical question. Before requesting a CBCT examination, the clinician should determine what additional information is required and whether that information is likely to influence diagnosis, treatment, or prognosis. If conventional radiography and clinical examination provide sufficient information for appropriate management, additional three-dimensional imaging may offer limited clinical benefit and may unnecessarily increase radiation exposure [3].

The principle of justification and optimization is therefore central to the appropriate use of CBCT. The smallest field of view and the lowest radiation exposure capable of answering the specific clinical question should be selected. At the same time, image quality must remain sufficient for the diagnostic task. This balance is particularly important in endodontics because many diagnostic questions involve small anatomical structures, such as accessory canals, narrow resorption defects, and fine fracture-related changes [3,6].

Overall, current evidence supports CBCT as a valuable decision-support tool in complex endodontic cases. Its greatest clinical benefit appears to occur when conventional imaging is inconclusive, root canal anatomy is complex, previous treatment has failed, surgical intervention is being considered, or traumatic and resorptive pathology is suspected [4,5]. However, CBCT should remain an adjunct to clinical examination and conventional radiography rather than becoming a routine imaging modality for every endodontic patient.

The clinical role of CBCT therefore extends beyond simply "seeing more." Its principal value lies in providing clinically actionable three-dimensional information that can reduce diagnostic uncertainty and facilitate individualized treatment planning. The next section will address an important aspect limiting this potential: technical factors affecting CBCT diagnostic accuracy, including voxel size, field of view, image resolution, and metal-related artefacts [6,13].

## 7. Technical Factors Affecting the Diagnostic Performance of CBCT

The diagnostic value of cone-beam computed tomography (CBCT) depends not only on the intrinsic advantages of three-dimensional imaging but also on the technical parameters used during image acquisition and reconstruction. Voxel size, field of view (FOV), exposure parameters, spatial resolution, image noise, and the presence of artefacts may all influence the visibility of anatomical structures and pathological changes. Consequently, appropriate protocol selection is essential to ensure that the acquired volume provides sufficient diagnostic information while avoiding unnecessary radiation exposure [1–3,6].

### 7.1. Voxel Size

Voxel size is one of the most important parameters influencing the spatial resolution of CBCT images. Smaller voxels theoretically allow visualization of smaller anatomical structures and may therefore be advantageous when evaluating narrow root canals, accessory canals, apical ramifications, or small resorptive defects. However, reducing voxel size may also increase image noise and radiation exposure depending on the acquisition protocol, meaning that the smallest available voxel should not automatically be considered optimal for every clinical indication [2,6].

Recent evidence provides important quantitative support for the influence of voxel size on endodontic diagnosis. A 2026 systematic review and meta-analysis by Mohammad-Rahimi et al. evaluated 15 studies

examining voxel sizes ranging from 75 to 400  $\mu\text{m}$ . The pooled diagnostic accuracy was approximately 80%, while subgroup analysis demonstrated significantly higher diagnostic accuracy for voxel sizes  $\leq 125 \mu\text{m}$  compared with voxel sizes  $>125 \mu\text{m}$ . Diagnostic accuracy was approximately 85% in the  $\leq 125 \mu\text{m}$  group compared with 75% in the  $>125 \mu\text{m}$  group [6].

These findings suggest that smaller voxel sizes may provide a meaningful advantage when detailed assessment of root canal anatomy is required. Nevertheless, the authors emphasized substantial heterogeneity between studies and noted that voxel size interacts with other imaging parameters. Therefore, voxel size should not be considered an isolated determinant of diagnostic performance [6].

The clinical significance of voxel size is particularly apparent when attempting to identify small or anatomically complex structures. Additional canals such as MB2 may have a narrow diameter and complex trajectory, making them susceptible to partial-volume effects. A smaller voxel may improve the ability to distinguish such structures from surrounding dentin. However, even high-resolution CBCT cannot guarantee detection of every canal, particularly when canals are severely calcified or obscured by artefacts [6–8].

## 7.2. Field of View

Field of view represents another important parameter in CBCT imaging. A smaller FOV limits the scanned anatomical region and may provide improved spatial resolution while reducing radiation exposure compared with larger-volume acquisitions. In endodontic applications, a limited FOV focused on the tooth or region of interest is generally preferable when it provides sufficient information to answer the specific clinical question [2,3].

The selection of FOV should therefore be based on the diagnostic indication. For assessment of a single tooth with suspected additional canal anatomy, a small-volume scan may be sufficient. In contrast, a larger FOV may be justified when multiple teeth, extensive periapical pathology, traumatic injuries, or anatomical structures extending beyond a single tooth require evaluation. The principle should always be to select the smallest volume capable of providing the necessary diagnostic information [3].

FOV also interacts with image resolution and radiation dose. A smaller FOV may permit acquisition at a higher spatial resolution without unnecessarily exposing larger regions of the patient. However, the actual relationship between FOV, voxel size, exposure parameters, and image quality depends on the specific CBCT device and acquisition protocol [2,3].

## 7.3. Image Resolution and Exposure Parameters

Image quality represents a balance between spatial resolution, contrast resolution, image noise, and radiation dose. Increasing exposure parameters may improve signal-to-noise ratio and reduce image noise, but excessive exposure is inconsistent with the principle of radiation optimization. Conversely, reducing exposure excessively may produce images with insufficient quality for reliable interpretation.

In endodontics, this balance is particularly important because many diagnostic questions involve small structures. Identification of additional canals, root fractures, and small resorptive defects may require relatively high spatial resolution. Nevertheless, the imaging protocol should be adapted to the specific diagnostic task rather than using a high-resolution protocol routinely [3,6].

The European Society of Endodontology emphasizes that CBCT should be prescribed only when the expected diagnostic benefit justifies the radiation exposure and that imaging parameters should be optimized for the individual clinical indication [3].

## 7.4. Metal and High-Density Artefacts

One of the most important limitations of dental CBCT is the presence of artefacts generated by high-density materials. Metallic posts, crowns, implants, orthodontic components, and some intracanal materials can produce beam-hardening, streaking, and shading artefacts. These artefacts may obscure anatomical structures and reduce the reliability of CBCT interpretation, particularly in previously treated teeth [12–14].

The problem is particularly relevant when diagnosing vertical root fractures. Root-filled teeth frequently contain gutta-percha or posts, both of which can produce image artefacts that obscure the fracture line or create structures that mimic a fracture. Consequently, the diagnostic performance of CBCT for vertical root fractures may be substantially lower in the presence of intracanal materials [12–14].

Metal artefact reduction (MAR) algorithms have been developed to reduce these effects. Although MAR may improve the visual quality of CBCT images in selected cases, its effect on diagnostic accuracy is not

uniform. Depending on the material, CBCT device, reconstruction algorithm, and anatomical region, MAR may either improve visualization or introduce secondary artefacts that complicate interpretation [13].

This limitation is important because improved visual appearance should not automatically be interpreted as improved diagnostic accuracy. The clinician must assess the original and processed images critically and consider whether an apparent finding is supported across multiple imaging planes and by the clinical presentation [13,14].

### **7.5. Interpretation and Observer-Related Factors**

CBCT interpretation is also influenced by the experience and training of the observer. Three-dimensional datasets contain considerably more information than conventional radiographs, and the interpretation of multiplanar reconstructions requires familiarity with normal anatomical variation and common artefacts. Differences in observer experience may therefore contribute to variability in diagnostic performance.

This is particularly relevant when assessing subtle findings such as narrow accessory canals, early resorption, or suspected vertical root fractures. A structure that appears suspicious on one reconstruction may represent a normal anatomical variation or an artefact when examined in another plane. Systematic evaluation of the entire volume is therefore preferable to interpretation based on a single reconstructed image [1–3].

### **7.6. Balancing Diagnostic Performance and Radiation Exposure**

The technical optimization of CBCT should ultimately be guided by the principle of achieving the lowest radiation exposure that provides adequate diagnostic information. Increasing spatial resolution may improve visualization of fine anatomical structures, but it should only be pursued when the additional resolution is clinically justified.

This principle is particularly important because recent evidence suggests that smaller voxel sizes can improve diagnostic accuracy for root canal anatomy, but the magnitude of benefit varies between clinical tasks and studies [6]. Therefore, the optimal CBCT protocol cannot be defined by a single voxel size or exposure setting for all endodontic indications.

Overall, the diagnostic performance of CBCT is determined by the interaction of multiple technical and observer-related factors. Voxel size, FOV, exposure parameters, image quality, artefacts, and interpretation expertise should be considered together when selecting and evaluating a CBCT examination. The most appropriate protocol is not necessarily the one that produces the highest-resolution image, but the one that provides sufficient information to answer the specific clinical question while maintaining radiation exposure as low as reasonably achievable [3,6].

The next section will address an increasingly important issue: the limitations, risks, and potential pitfalls of CBCT in endodontics, including false-positive findings, overdiagnosis, artefacts, radiation considerations, and the danger of using CBCT as a substitute for clinical examination.

## **8. Limitations and Potential Pitfalls of CBCT in Endodontics**

Despite its considerable diagnostic advantages, cone-beam computed tomography (CBCT) has several limitations that must be considered before its use in endodontic diagnosis and treatment planning. Three-dimensional imaging provides substantially more anatomical information than conventional radiography, but increased information does not necessarily equate to increased diagnostic certainty. Radiation exposure, image artefacts, technical limitations, false-positive findings, and observer-related factors may all influence the clinical value of CBCT [1–3,12–14].

One of the most important limitations is radiation exposure. Although dental CBCT generally delivers a lower effective dose than conventional medical computed tomography, its radiation exposure is still greater than that associated with a single intraoral periapical radiograph. The actual dose varies considerably according to the CBCT device, field of view, voxel size, exposure parameters, and acquisition protocol. Consequently, CBCT should not be obtained simply because three-dimensional imaging is available. Its use should be justified by a specific clinical indication and a reasonable expectation that the additional information will influence diagnosis, treatment planning, or prognosis [2,3].

The principle of radiation optimization is therefore central to endodontic CBCT. The smallest field of view capable of answering the clinical question should be selected, while exposure parameters should be adjusted to provide adequate image quality without unnecessary radiation. A recent evidence-based review

emphasized that limited-volume CBCT examinations are generally preferable for endodontic indications when they provide sufficient diagnostic information, because larger fields of view may substantially increase the effective radiation dose without necessarily improving the diagnostic value for a localized clinical problem.

Another important limitation is the presence of image artefacts. Dental CBCT is susceptible to motion artefacts, image noise, scatter, beam hardening, and streaking. High-density materials such as metallic restorations, posts, implants, and intracanal materials may produce particularly pronounced artefacts. These distortions can obscure anatomical structures or pathological changes and may occasionally produce appearances that mimic disease [1,2,13,14]. Recent evidence confirms that artefacts remain one of the major factors limiting CBCT interpretation in endodontically treated teeth.

The problem is particularly significant in the diagnosis of vertical root fractures. Root-filled teeth frequently contain gutta-percha and, in some cases, metallic posts or other restorative materials. Beam-hardening and scatter generated by these materials may obscure a true fracture line or create radiolucent structures that resemble a fracture. Consequently, a fracture-like appearance on CBCT should not automatically be interpreted as definitive evidence of a vertical root fracture [12–14].

Metal artefact reduction algorithms have been developed to improve image quality in such situations. However, their diagnostic benefit is inconsistent. Although these algorithms may reduce certain forms of artefact, they can also introduce secondary distortions or alter the appearance of anatomical structures. Therefore, the use of a metal artefact reduction algorithm should not be regarded as a guarantee of improved diagnostic accuracy [13].

Another potential pitfall is false-positive diagnosis. Because CBCT can detect very subtle changes in bone density and anatomical structures, clinicians may identify findings that are difficult to interpret clinically. Normal anatomical structures, variations in trabecular bone, the mental foramen, incisive canal, maxillary sinus, or other anatomical landmarks may occasionally resemble pathological changes when viewed in isolation. Adequate knowledge of normal anatomy and systematic assessment of multiplanar images are therefore essential [1–3].

The increased sensitivity of CBCT may also contribute to overdiagnosis. Detection of a small radiolucency or subtle anatomical abnormality does not necessarily mean that immediate treatment is required. A radiographic finding should always be interpreted together with the patient's symptoms, clinical examination, pulp sensibility testing, periodontal findings, previous treatment history, and conventional radiographs. The decision to intervene should be based on the overall clinical diagnosis rather than on the presence of an isolated CBCT finding [3–5].

This issue is particularly relevant because CBCT can influence clinicians toward more invasive treatment options. Recent systematic evidence has demonstrated that CBCT may alter treatment planning and increase diagnostic confidence in complex endodontic cases, but changes in treatment planning do not necessarily indicate improved patient outcomes. In some situations, additional information may lead to a recommendation for surgery or extraction that would not have been considered on the basis of conventional imaging alone [4,5]. Therefore, the clinical consequences of CBCT findings should be carefully considered.

The distinction between diagnostic accuracy and clinical efficacy is particularly important. A CBCT examination may demonstrate superior sensitivity for detecting a particular anatomical or pathological feature without necessarily improving the long-term outcome of treatment. Earlier systematic evidence emphasized that much of the CBCT literature has focused on technical image quality and diagnostic accuracy, while substantially fewer studies have directly evaluated whether CBCT improves treatment outcomes or patient-centered clinical endpoints.

Observer experience represents another important source of variability. Interpretation of CBCT requires the ability to navigate multiplanar datasets, recognize normal anatomical structures, identify artefacts, and distinguish clinically relevant abnormalities from incidental findings. Differences in examiner training and experience may therefore affect diagnostic performance. This is particularly important when assessing subtle findings such as accessory canals, early resorption, and suspected root fractures [1–3,13].

The possibility of incidental findings should also be considered. Because CBCT examinations frequently include anatomical regions beyond the immediate tooth of interest, unrelated abnormalities may be detected. These may include changes involving the maxillary sinuses, surrounding bone, adjacent teeth, or other anatomical structures. While recognition of incidental pathology can represent an additional clinical benefit, it also creates a responsibility for appropriate interpretation and management of findings outside the original diagnostic question [1–3].

Another limitation concerns the relationship between voxel size and image quality. Although smaller voxels may improve visualization of fine anatomical structures, they are not automatically associated with superior diagnostic performance in every situation. Image noise, contrast, exposure parameters, and the characteristics of the CBCT device interact with voxel size and can influence the final image. Recent meta-analytic evidence suggests improved diagnostic accuracy for root canal anatomy with voxel sizes  $\leq 125 \mu\text{m}$ , but substantial heterogeneity between studies prevents the establishment of a universal optimal voxel size for all endodontic applications [6].

Furthermore, CBCT does not provide direct information regarding the biological status of the pulp or periapical tissues. A three-dimensional radiographic image can demonstrate structural changes but cannot independently determine whether a pulp is vital, necrotic, inflamed, or capable of healing. Similarly, CBCT cannot reliably establish the histopathological diagnosis of a periapical lesion. Radiographic interpretation must therefore remain integrated with clinical examination and biological assessment [1–5].

The limitations of CBCT are particularly important when evaluating treatment outcomes. Periapical lesions associated with root-filled teeth may be partially obscured by artefacts produced by root filling materials. Consequently, the diagnostic performance of CBCT for detecting periapical pathology may be reduced in previously treated teeth compared with untreated teeth [12,13]. This reinforces the importance of considering the presence of existing treatment materials when interpreting follow-up CBCT examinations.

Overall, CBCT should be regarded as a powerful but selective diagnostic tool. Its greatest value occurs when conventional clinical and radiographic examination cannot adequately answer a specific diagnostic question and when three-dimensional information is likely to influence management. Conversely, routine use without a clear clinical indication may expose patients to unnecessary radiation and increase the likelihood of incidental findings, artefact-related misinterpretation, and potentially unnecessary treatment [1–5].

The appropriate use of CBCT therefore requires a balance between diagnostic benefit, radiation exposure, technical limitations, and clinical consequences. Rather than asking whether CBCT is "better" than conventional radiography in general, the more clinically relevant question is whether CBCT provides additional information that is necessary for the management of the individual patient. This patient-specific approach remains fundamental to evidence-based endodontic imaging [3–5].

## **9. CBCT-Assessed Outcomes of Endodontic Treatment**

Assessment of endodontic treatment outcomes traditionally relies on clinical examination and periapical radiography. The principal radiographic objective is to determine whether periapical inflammation has resolved or whether a pre-existing periapical lesion has decreased in size. However, conventional radiography provides only a two-dimensional representation of three-dimensional anatomical structures and may therefore underestimate the extent of residual periapical disease. Cone-beam computed tomography (CBCT) has increasingly been used to overcome some of these limitations and provide a more detailed assessment of periapical healing following root canal treatment [1,2,15].

The greater sensitivity of CBCT for detecting periapical changes has important implications for the assessment of treatment success. A tooth that appears radiographically healthy on a conventional periapical image may demonstrate residual periapical changes on CBCT. Consequently, treatment outcome estimates based on CBCT may be lower than those obtained using conventional radiography, particularly when complete radiographic resolution of a periapical lesion is required to define treatment success [9,10,15].

A recent systematic review and meta-analysis by Brochado Martins et al. evaluated CBCT-assessed outcomes of primary root canal treatment and retreatment and included 19 studies. When relatively less stringent criteria were applied, the pooled periapical healing rate was approximately 87% at the tooth level. In contrast, when strict criteria requiring complete resolution of the periapical lesion were applied, the pooled healing rate decreased to approximately 36%. Similarly, the weighted pooled success rate was approximately 85% using loose criteria compared with approximately 45% using strict criteria [15].

These findings demonstrate that the definition of treatment success has a major influence on reported outcomes. A reduction in lesion size may represent substantial biological healing even when complete radiographic disappearance has not yet occurred. Conversely, requiring complete resolution of a periapical lesion on CBCT may classify some clinically successful treatments as unsuccessful despite evidence of progressive healing. Therefore, CBCT-based outcome assessment requires clearly defined and clinically meaningful criteria [15].

Another systematic review and meta-analysis published in 2025 similarly reported an estimated overall success rate of approximately 85% using loose criteria and approximately 41% using strict criteria when nonsurgical root canal treatment and retreatment were evaluated using CBCT. The authors emphasized that the available evidence was characterized by substantial heterogeneity and that the findings should therefore be interpreted cautiously [15].

The discrepancy between CBCT and conventional radiographic assessment can be explained partly by the greater sensitivity of three-dimensional imaging. CBCT can identify small areas of residual or recurrent periapical bone destruction that may be obscured by anatomical structures on conventional radiographs. Although this provides a more detailed assessment of periapical tissues, it also creates a potential risk of defining clinically acceptable healing as treatment failure solely because minor radiographic abnormalities remain visible [9,10,15].

CBCT may be particularly valuable in the assessment of previously treated teeth. Persistent or recurrent apical periodontitis may result from untreated canals, inadequate cleaning and shaping, insufficient obturation, coronal leakage, or persistent extraradicular infection. CBCT can provide simultaneous information regarding periapical bone changes and the anatomical or technical factors that may have contributed to treatment failure [4,5,15].

The identification of missed canals is particularly relevant in this context. A recent systematic review and meta-analysis demonstrated an association between canals missed during root canal treatment and post-treatment apical periodontitis when missed canals were identified using CBCT. This reinforces the role of three-dimensional imaging in explaining persistent disease in previously treated teeth and illustrates how CBCT findings may connect anatomical treatment deficiencies with clinical outcomes.

CBCT can also provide prognostic information by allowing assessment of anatomical and treatment-related factors associated with healing. The 2025 meta-analysis by Brochado Martins et al. identified several potential predictors of treatment outcome, including the number of treatment visits, irrigant type, tooth type, operator experience, apical preparation size and taper, and obturation technique [15].

Nevertheless, CBCT should not automatically be used for routine follow-up of every endodontically treated tooth. Although it provides greater diagnostic sensitivity, the increased radiation exposure and the possibility of detecting minor residual abnormalities must be balanced against the clinical benefit. The most recent evidence suggests that routine CBCT-based evaluation of treatment outcomes may not be necessary when conventional radiographic assessment provides sufficient information and the patient is clinically asymptomatic [15].

The distinction between disease detection and treatment outcome assessment is therefore important. CBCT may be superior to conventional radiography for identifying residual periapical lesions, but increased detection does not necessarily mean that treatment outcomes are clinically worse. A small residual radiolucency may represent incomplete healing rather than persistent infection, and the biological significance of such a finding must be interpreted in the context of symptoms, lesion evolution, treatment quality, and the time elapsed since treatment [9,10,15].

The timing of follow-up is another important consideration. Periapical healing is a dynamic biological process, and complete radiographic resolution may require an extended period following treatment. Early CBCT examination may identify residual defects that subsequently resolve. Consequently, the use of strict CBCT criteria at an early follow-up stage may underestimate the eventual success of treatment [15].

CBCT may therefore be most valuable when the clinical course is uncertain. In a symptomatic patient with persistent periapical pathology, CBCT can help determine whether the problem is associated with a missed canal, inadequate treatment, persistent periapical disease, root fracture, or another pathological process. Similarly, CBCT may be useful before retreatment or endodontic surgery when conventional radiography cannot adequately explain the clinical situation [4,5,15].

Overall, CBCT provides a highly sensitive method for assessing periapical healing and treatment outcomes, but its interpretation requires an understanding of the differences between radiographic healing and biological success. CBCT-based success rates are generally lower when strict criteria requiring complete lesion resolution are applied, whereas more permissive criteria produce estimates closer to those traditionally reported using conventional radiography [15].

Therefore, CBCT should be considered a valuable problem-solving and outcome-assessment tool rather than a mandatory routine examination after endodontic treatment. Its greatest clinical value is likely to occur in cases with persistent symptoms, uncertain healing, suspected treatment deficiencies, retreatment, or complex anatomical and pathological findings. When used selectively and interpreted together with clinical findings and conventional radiographs, CBCT can provide important additional information without unnecessarily increasing radiation exposure [3–5,15].

## **10. Current Recommendations and Clinical Applications of CBCT in Endodontics**

The increasing availability of cone-beam computed tomography (CBCT) has expanded the diagnostic capabilities of contemporary endodontics; however, its use should remain guided by a clearly defined clinical indication. Current recommendations emphasize that CBCT should not replace conventional intraoral radiography as the routine imaging modality for every endodontic patient. Instead, CBCT should be prescribed when the additional three-dimensional information is expected to provide clinically relevant information that cannot be obtained adequately using conventional imaging [1–3].

The European Society of Endodontology recommends that CBCT should be considered when conventional radiographic examination does not provide sufficient information for diagnosis or treatment planning and when the result is likely to influence clinical management [3]. This approach is consistent with the broader principle of radiation protection, according to which every radiographic examination should be justified by an expected diagnostic benefit. The decision to obtain a CBCT scan should therefore begin with a specific clinical question rather than with the availability of the technology.

One of the most appropriate indications for CBCT is the evaluation of complex root canal anatomy. When conventional radiographs suggest unusual root morphology, additional roots, severe curvature, C-shaped anatomy, dens invaginatus, or other developmental abnormalities, CBCT may provide valuable three-dimensional information regarding the number, trajectory, and relationship of individual canals [1,2]. This information may facilitate access cavity design, canal localization, and selection of an appropriate instrumentation strategy.

CBCT is also particularly useful when an additional canal is suspected but cannot be confidently identified clinically. The detection of additional canals, particularly MB2 in maxillary molars, represents one of the most established applications of CBCT in endodontics. Evidence demonstrates high diagnostic accuracy for additional canal detection, although CBCT should remain complementary to clinical examination, magnification, and careful exploration of the pulp chamber [7,8].

Another important indication is the assessment of persistent or recurrent disease following root canal treatment. When a previously treated tooth remains symptomatic or demonstrates persistent periapical pathology, CBCT may reveal untreated canals, complex root morphology, periapical lesions, root fractures, or other factors that are difficult to evaluate using conventional radiography [4,5]. The information obtained may help determine whether nonsurgical retreatment, endodontic surgery, observation, or extraction represents the most appropriate treatment strategy.

CBCT may also provide substantial benefits before endodontic microsurgery. Three-dimensional visualization allows assessment of the location and extent of periapical lesions, cortical bone thickness, root morphology, and the proximity of relevant anatomical structures. This information can facilitate surgical access and potentially reduce the risk of damaging adjacent structures [1,2,5].

Suspected root resorption represents another situation in which CBCT may provide clinically important additional information. Three-dimensional imaging can establish the location and extent of external resorptive defects and their relationship to the root canal. This may influence the feasibility of conservative treatment and assist in determining the prognosis of the affected tooth [11].

The use of CBCT in suspected vertical root fracture requires greater caution. Although CBCT can provide valuable information regarding fracture-associated bone loss and root morphology, its diagnostic performance may be compromised by intracanal materials and metallic restorations. A negative CBCT examination cannot reliably exclude a fracture, while artefacts may produce findings that mimic a fracture line [12–14]. Therefore, CBCT findings should always be interpreted alongside clinical and periodontal findings.

### **10.1. Selection of Field of View and Voxel Size**

Once CBCT examination has been justified, the imaging protocol should be optimized for the specific clinical question. A limited field of view (FOV) is generally preferred for localized endodontic problems because it restricts radiation exposure and can provide adequate spatial resolution for evaluation of the tooth or region of interest [2,3].

For example, a small-volume CBCT examination may be appropriate when investigating a suspected additional canal in a single molar, while a larger field may be justified when multiple teeth, extensive pathology, or broader anatomical relationships must be evaluated. The principle should therefore be to use the smallest FOV capable of answering the clinical question.

Voxel size should similarly be selected according to the diagnostic task. Smaller voxels may be advantageous when evaluating fine anatomical structures such as accessory canals, narrow resorptive defects, or subtle anatomical variations. Recent evidence indicates that voxel sizes  $\leq 125\ \mu\text{m}$  may provide higher diagnostic accuracy for assessment of root canal anatomy compared with larger voxel sizes, although the optimal protocol remains dependent on the CBCT device and clinical indication [6].

Importantly, the smallest possible voxel should not automatically be selected. Increasing spatial resolution may be accompanied by increased image noise and radiation exposure, and the additional diagnostic information may be clinically insignificant in some situations. Appropriate CBCT selection therefore requires balancing spatial resolution against radiation dose and the complexity of the diagnostic question [3,6].

### **10.2. The ALARA Principle**

Radiation protection represents a fundamental component of CBCT prescribing. The ALARA principle — "as low as reasonably achievable" — requires clinicians to minimize radiation exposure while maintaining sufficient image quality for the intended diagnostic task.

In practical terms, this means that clinicians should avoid unnecessarily large FOVs, unnecessarily high-resolution protocols, and repeated CBCT examinations when previous imaging already provides sufficient information. The selected protocol should be tailored to the patient, the tooth or region being evaluated, and the specific clinical question [2,3].

The importance of appropriate protocol selection is particularly relevant because studies demonstrate considerable variation in CBCT acquisition parameters among dental professionals. Surveys indicate that many clinicians do not consistently consider voxel size, FOV, and other technical parameters when requesting CBCT examinations. This emphasizes the importance of continuing education and familiarity with CBCT technology among endodontic practitioners.

### **10.3. CBCT Interpretation**

Appropriate prescription is only one component of safe CBCT use. The resulting dataset must also be interpreted systematically by a clinician with adequate knowledge of CBCT anatomy, pathology, and artefacts. A structured interpretation process involving axial, sagittal, and coronal planes can reduce the risk of overlooking clinically relevant findings [1,2].

CBCT interpretation should begin with the clinical question but should not be limited exclusively to the tooth being investigated. Unexpected findings involving adjacent teeth, bone, or surrounding anatomical structures may be identified during evaluation of the CBCT volume. Therefore, clinicians should recognize their responsibility to appropriately evaluate the entire acquired volume or ensure that it is reviewed by an appropriately trained professional.

A systematic approach is particularly important when assessing suspected root fractures, resorption, or complex canal anatomy. Findings should be assessed across multiple planes and, when possible, correlated with clinical examination and conventional radiographic findings. This approach reduces the likelihood that an isolated artefact or anatomical variation will be misinterpreted as pathology [1–3,13,14].

### **10.4. CBCT and Emerging Digital Endodontics**

The role of CBCT is also expanding beyond conventional diagnosis. Three-dimensional CBCT datasets can be integrated with intraoral scans and digital planning software to facilitate guided endodontic procedures. Static and dynamic navigation techniques have been developed for challenging cases involving calcified canals, anatomical abnormalities, endodontic microsurgery, and other situations where conventional access may carry a high risk of unnecessary tooth structure removal.

This development represents an important transition from CBCT as a purely diagnostic modality toward CBCT as a component of digitally assisted treatment planning. Three-dimensional anatomical information can be transferred into virtual planning environments, allowing clinicians to determine an optimal access trajectory or surgical approach before intervention. Such applications may be particularly valuable in teeth with severely calcified canals or complex root morphology.

Future developments may further integrate CBCT with artificial intelligence, automated anatomical segmentation, and dynamic navigation. These technologies could potentially assist in identifying additional canals, detecting pathological changes, and planning minimally invasive access cavities. However, their clinical implementation requires appropriate validation and should not replace clinician judgment [1,2].

Overall, contemporary recommendations support a selective, question-driven approach to CBCT prescription. The examination is particularly valuable when complex anatomy, additional canals, persistent disease, root resorption, suspected root fracture, traumatic injury, or surgical treatment planning creates diagnostic uncertainty [3–5,11–14].

The optimal use of CBCT can therefore be summarized by four principles: justify the examination, optimize the acquisition protocol, interpret the entire volume systematically, and integrate CBCT findings with clinical information. When these principles are followed, CBCT can provide substantial diagnostic and treatment-planning benefits while limiting unnecessary radiation exposure.

CBCT should consequently be regarded not as a replacement for conventional endodontic diagnosis but as a targeted three-dimensional diagnostic tool whose value is greatest when its additional information has a realistic potential to change clinical management [1–5].

## 11. Future Perspectives

The role of cone-beam computed tomography (CBCT) in endodontics is likely to expand considerably as imaging technology becomes increasingly integrated with digital dentistry, artificial intelligence, and computer-assisted treatment planning. Current developments are moving beyond the traditional use of CBCT as a diagnostic imaging modality toward its incorporation into individualized treatment planning, guided procedures, automated image analysis, and potentially real-time clinical navigation. These developments may further increase the clinical value of three-dimensional imaging while simultaneously addressing some of its current limitations [1,2].

One of the most promising areas of development is the application of artificial intelligence (AI) and machine learning to CBCT interpretation. Deep-learning algorithms, particularly convolutional neural networks, are increasingly being investigated for the automated detection and classification of anatomical and pathological findings. Potential applications include identification of periapical lesions, detection of additional root canals, segmentation of roots and canals, recognition of root morphology, and identification of treatment-related abnormalities. Recent reviews indicate that AI-based systems may achieve high diagnostic performance in selected imaging tasks and could potentially assist clinicians in interpreting complex CBCT datasets [1,2].

Automated segmentation of root canals and periapical lesions may be particularly valuable in endodontics. Manual interpretation of three-dimensional CBCT datasets can be time-consuming and requires substantial experience. AI-assisted segmentation could potentially allow rapid visualization of individual roots, canals, and pathological structures, providing clinicians with a more intuitive representation of complex anatomy. Such systems may also reduce interobserver variability and assist less experienced clinicians in recognizing anatomical variations [1,2].

However, the implementation of AI in clinical endodontics remains subject to important limitations. Many currently available models have been developed using relatively limited or highly selected datasets, and their performance may decrease when applied to CBCT images acquired using different devices, imaging protocols, voxel sizes, or patient populations. External validation, standardized datasets, transparency of algorithms, and assessment of clinically meaningful outcomes will therefore be essential before AI-based CBCT interpretation can become a routine component of endodontic practice.

Another important direction is the integration of CBCT with intraoral scanning and digital treatment planning. CBCT provides information regarding internal dental anatomy, while intraoral scanning provides highly accurate information about external tooth morphology and occlusion. Combining these datasets creates a comprehensive three-dimensional representation of the tooth that can be used for individualized treatment planning. This approach is particularly relevant to guided endodontics, where the planned access trajectory can be determined before treatment begins.

Guided endodontics represents one of the most clinically promising applications of CBCT-based digital planning. Static-guided endodontics can combine CBCT datasets with intraoral scans to create a virtual access trajectory and subsequently fabricate a three-dimensional printed guide. This approach may be particularly useful in teeth with severely calcified or obliterated canals, unusual root morphology, or other anatomical conditions in which conventional access preparation carries a substantial risk of excessive dentin removal or procedural errors [1,2].

Dynamic navigation represents a further development of this concept. Rather than relying on a prefabricated static guide, dynamic systems can track the position of the handpiece or bur in real time and compare it with the previously planned trajectory. This may allow the operator to modify the access path during

treatment while maintaining a predetermined three-dimensional orientation. The combination of CBCT-based planning and dynamic navigation could therefore provide greater flexibility while retaining the anatomical precision of computer-assisted treatment planning.

Future CBCT systems may also incorporate improved artefact reduction technologies. Metal artefacts remain a significant limitation, particularly in root-filled teeth and teeth containing posts or extensive restorations. Conventional metal artefact reduction algorithms can improve image quality in selected situations, but their effect on diagnostic accuracy remains variable. Development of advanced reconstruction algorithms, including machine-learning-based approaches, may provide improved correction of beam-hardening and other artefacts while preserving diagnostically relevant anatomical information [13].

Another important area of future development is dose optimization. Increasing diagnostic capabilities should not result in unnecessary radiation exposure. Future CBCT systems are likely to incorporate more sophisticated acquisition protocols that dynamically balance voxel size, image noise, field of view, and radiation dose according to the specific clinical indication. Such approaches may allow high-resolution imaging of small anatomical structures while maintaining radiation exposure at an appropriately low level [3,6].

The development of personalized CBCT protocols may be particularly relevant in endodontics because different diagnostic questions require different levels of spatial resolution. Detection of a large periapical lesion may not require the same imaging parameters as visualization of an accessory canal or a small resorptive defect. Consequently, future systems may increasingly incorporate indication-specific protocols designed to optimize diagnostic performance for the particular anatomical or pathological problem being investigated [3,6].

The combination of CBCT, AI, and digital navigation may eventually facilitate patient-specific endodontic treatment planning. Rather than applying standardized access and instrumentation protocols to all teeth of a given type, clinicians could potentially use three-dimensional anatomical data to determine the optimal access trajectory, canal identification strategy, and treatment approach for each individual tooth. This could contribute to more conservative treatment and improved preservation of healthy tooth structure.

Another potential development is the integration of CBCT-based imaging with predictive analytics. AI systems may eventually be able to combine anatomical characteristics, periapical findings, treatment variables, and patient-specific factors to estimate the probability of treatment success or failure. Such systems could assist clinicians in determining whether primary treatment, retreatment, surgery, or extraction represents the most appropriate option. However, predictive models should be validated against meaningful long-term clinical outcomes before they are used to guide irreversible treatment decisions [4,5].

The increasing sophistication of digital technologies also raises important ethical and clinical considerations. AI-generated diagnostic suggestions should not be considered equivalent to independent clinical diagnosis. Errors in automated segmentation or classification may lead to inappropriate treatment decisions if clinicians become overly dependent on algorithmic recommendations. Future implementation should therefore emphasize AI-assisted rather than AI-replacing clinical decision-making, with clinicians maintaining responsibility for integrating imaging findings with patient history, clinical examination, and biological considerations.

Future research should also focus on establishing standardized methodologies for evaluating AI-assisted CBCT analysis. Studies should include diverse patient populations, different CBCT devices, varying imaging parameters, and independent external validation. Importantly, research should move beyond reporting diagnostic accuracy alone and determine whether AI-assisted CBCT interpretation actually improves treatment planning, reduces procedural complications, preserves tooth structure, or improves long-term treatment outcomes [4,5].

Overall, the future of CBCT in endodontics is likely to involve a transition from passive image interpretation toward integrated three-dimensional digital treatment planning. The combination of CBCT with AI, intraoral scanning, guided endodontics, dynamic navigation, and advanced artefact reduction has the potential to substantially improve the precision and predictability of endodontic treatment. Nevertheless, technological advancement should remain guided by the same fundamental principles that currently govern CBCT use: clinical justification, radiation optimization, appropriate image interpretation, and integration of imaging findings with comprehensive clinical assessment [1–6].

CBCT is therefore likely to remain a central component of digital endodontics, but its future clinical value will depend not simply on producing increasingly detailed images, but on converting three-dimensional information into accurate, clinically useful, and patient-specific treatment decisions.

**Author's contributions:**

Conceptualization: Ewa Jurkowska, Zofia Wiśniewska

Methodology: Ewa Jurkowska

Software: Zofia Wiśniewska

Check: Zofia Wiśniewska

Formal Analysis: Zofia Wiśniewska

Investigation: Ewa Jurkowska, Zofia Wiśniewska

Writing - Original draft: Ewa Jurkowska

Writing - Review & editing: Ewa Jurkowska, Zofia Wiśniewska

Visualization: Ewa Jurkowska

All authors have read and agreed with the published version of the manuscript.

**Conflict of Interest Statement:** The authors have declared no conflicts of interest.

**Declaration of the use of generative AI and AI-assisted technologies in the writing process.**

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed.

**REFERENCES**

1. Patel, S., Brown, J., Pimentel, T., Kelly, R. D., Abella, F., & Durack, C. (2019). Cone beam computed tomography in endodontics – a review of the literature. *Int Endod J*, 52(8), 1138–1152. <https://doi.org/10.1111/iej.13115>
2. Chan, F., Brown, L. F., & Parashos, P. (2023). CBCT in contemporary endodontics. *Aust Dent J*, 68(Suppl 1), S39–S55. <https://doi.org/10.1111/adj.12995>
3. Patel, S., Brown, J., Semper, M., Abella, F., & Mannocci, F. (2019). European Society of Endodontology position statement: Use of cone beam computed tomography in endodontics: European Society of Endodontology (ESE) developed by. *Int Endod J*, 52(11), 1675–1678. <https://doi.org/10.1111/iej.13187>
4. Trindade, J. L., Maracci, L. M., Morgental, R. D., Liedke, G. S., & Bier, C. A. S. (2025). Cone beam computed tomography impact on diagnosis, treatment planning and confidence in endodontic decision-making: A systematic review. *Aust Endod J*, 51(2), 536–553. <https://doi.org/10.1111/aej.12964>
5. Tay, K. X., Lim, L. Z., Goh, B. K. C., & Yu, V. S. H. (2022). Influence of cone beam computed tomography on endodontic treatment planning: A systematic review. *J Dent*, 127, 104353. <https://doi.org/10.1016/j.jdent.2022.104353>
6. Mohammad-Rahimi, H., Ourang, S. A., Nosrat, A., Spin-Neto, R., & Pauwels, R. (2026). Effect of voxel size on cone-beam computed tomography-based assessment of root canal anatomy: A systematic review and meta-analysis. *Int Endod J*, 59(4), 574–589. <https://doi.org/10.1111/iej.70092>
7. Aung, N. M., & Myint, K. K. (2021). Diagnostic accuracy of CBCT for detection of second canal of permanent teeth: A systematic review and meta-analysis. *Int J Dent*, 2021, 1107471. <https://doi.org/10.1155/2021/1107471>
8. Parker, J., Mol, A., Rivera, E. M., & Tawil, P. (2017). CBCT uses in clinical endodontics: The effect of CBCT on the ability to locate MB2 canals in maxillary molars. *Int Endod J*, 50(12), 1109–1115. <https://doi.org/10.1111/iej.12736>
9. Kruse, C., Spin-Neto, R., Wenzel, A., & Kirkevang, L. L. (2015). Cone beam computed tomography and periapical lesions: A systematic review analysing studies on diagnostic efficacy by a hierarchical model. *Int Endod J*, 48(9), 815–828. <https://doi.org/10.1111/iej.12388>
10. Leonardi Dutra, K., Haas, L., Porporatti, A. L., Flores-Mir, C., Nascimento Santos, J., Mezzomo, L. A., et al. (2016). Diagnostic accuracy of cone-beam computed tomography and conventional radiography on apical periodontitis: A systematic review and meta-analysis. *J Endod*, 42(3), 356–364. <https://doi.org/10.1016/j.joen.2015.12.015>
11. Yi, J., Sun, Y., Li, Y., Li, C., Li, X., & Zhao, Z. (2017). Cone-beam computed tomography versus periapical radiograph for diagnosing external root resorption: A systematic review and meta-analysis. *Angle Orthod*, 87(2), 328–337. <https://doi.org/10.2319/061916-481.1>
12. PradeepKumar, A. R., Shemesh, H., Nivedhitha, M. S., Hashir, M. M. J., Arockiam, S., Uma Maheswari, T. N., et al. (2021). Diagnosis of vertical root fractures by cone-beam computed tomography in root-filled teeth with confirmation by direct visualization: A systematic review and meta-analysis. *J Endod*, 47(8), 1198–1214. <https://doi.org/10.1016/j.joen.2021.04.022>
13. Fontenele, R. C., Machado, A. H., de Oliveira Reis, L., & Freitas, D. Q. (2021). Influence of metal artefact reduction tool on the detection of vertical root fractures involving teeth with intracanal materials in cone beam computed tomography images: A systematic review and meta-analysis. *Int Endod J*, 54(10), 1769–1781. <https://doi.org/10.1111/iej.13569>

14. Shokri, A., Salemi, F., Taherpour, T., Karkehabadi, H., et al. (2024). Is cone-beam computed tomography more accurate than periapical radiography for detection of vertical root fractures? a systematic review and meta-analysis. *BMC Med Imaging*, 24, 286. <https://doi.org/10.1186/s12880-024-01472-5>
15. Brochado Martins, J. F., Georgiou, A. C., Nunes, P. D., de Vries, R., Afreixo, V. M. A., da Palma, P. J. R., & Shemesh, H. (2025). CBCT-Assessed outcomes and prognostic factors of primary endodontic treatment and retreatment: A systematic review and meta-analysis. *J Endod*, 51(6), 687–706. <https://doi.org/10.1016/j.joen.2025.03.004>