Open Journal of Stomatology, 2017, 7, 314-326
http://www.scirp.org/journal/ojst
ISSN Online: 2160-8717
ISSN Print: 2160-8709

Clinical Endodontic Applications of Cone Beam-Computed Tomography in Modern Dental Practice

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How to cite this paper: Galicia, J.C., Kawilarang, J. and Tawil, P.Z. (2017) Clinical Endodontic Applications of Cone Beam-Computed Tomography in Modern Dental Practice. *Open Journal of Stomatology*, **7**, 314-326.
https://doi.org/10.4236/ojst.2017.77026

Received: June 29, 2017
Accepted: July 18, 2017
Published: July 21, 2017

Abstract

Nearly two decades since Cone Beam-Computed Tomography (CBCT) was introduced in dentistry, this technology has been proven to be a useful asset in modern dental practice. The information gleaned from a CBCT scan influences treatment decisions and prognostication of challenging endodontic cases. The authors present six cases that utilized CBCT to diagnose vertical root fracture, to assess resorption, to guide the clinician in overcoming anatomical complexities, to hurdle diagnostic dilemmas and to perform pre-surgical evaluation. Initially, a thorough clinical assessment was performed; however, conventional periapical radiographs were not able to provide sufficient information to arrive at a definite diagnosis or a thorough treatment plan. CBCT was therefore deemed helpful for these cases. Clearly, there are advantages to using CBCT. With a better understanding of each case, the clinician can plan a definitive treatment plan and offer a clearer case prognosis to their patient.

Keywords

Endodontics, Cone-Beam Computed Tomography, Case Reports, Radiography

1. Introduction

Imaging is essential in various phases of clinical endodontics. For over 50 years, conventional two-dimensional radiographs have been used in endodontics to diagnose, treatment plan and assess outcome of a three-dimensional reality. Given the two-dimensional nature of conventional radiographs, limited information can be interpreted [1]. Image distortion, regional anatomy as well as superimposition of both the teeth and surrounding dentoalveolar structures can further add to interpretation problems [2] [3].

Cone Beam-Computed Tomography (CBCT) produces three-dimensional images and multilayer scans of the maxillofacial structures that enable clinicians to visualize the dentition, the maxillofacial skeleton, and the relationship of anatomic structures in 3-D at a much lower radiation compared to a conventional computed tomography used in medicine [4] [5]. It utilizes an extra-oral scanner to create images using effective doses ranging from 5 to 652 μSv for adults and 7 to 521 μSv for children in a small field of view (FOV) scan [6] [7] [8]. The effective dose for one digital PA radiograph is from 4 to 6 μSv [6] [9].

The following cases and the discussion thereafter highlight the importance of CBCT in modern practice. Endodontic diagnoses were made based on the guidelines set by the American Association of Endodontists (AAE) [10]. Clinical examination and testing were carried out on the tooth in question and its adjacent teeth using conventional methods [11] [12]. Cold, EPT (if no response to cold), percussion, palpation, probing and mobility assessment were performed. History of present illness was also recorded. For 3D imaging, the Accuitomo 170 (J. Morita, Irvine, CA) CBCT machine was used. For all the cases presented below (all adults), the following settings were employed: FOV size: 4 × 4 cm with a resolution of 80 μm; KV: 80; mA: 3. The effective dose for this setting on a lower molar region was 43 μSv according to Ludlow and co-authors [8]. The Accuitomo 170 manufacturer estimated the effective dose for that setting to be between 11 and 38 μSv for a lower molar depending on the rotation (180˚ or 360˚), time and desired resolution. For maxillary and anterior jaw regions, the effective dose is much lower [13]. *In-vivo* 5 imaging software (Anatomage, San Jose, CA) was used to analyze the scans.

2. Case Reports

2.1. Case 1: Diagnosis and Canal Determination

A healthy male in his forties was referred for non-surgical root canal treatment (NSRCT) of tooth #14. His chief complaint was continuous, low-grade pain and history of swelling that the patient localized on soft tissue above #14. Patient had good oral hygiene. No draining sinus tract or parulis was noted. All posterior teeth on the left upper jaw were clinically examined. No caries was noted, some teeth had composite restorations or full coverage crown with intact margins. Except for tooth #15, the rest of the teeth were diagnosed with normal pulp (NP). All teeth had normal apical tissues (NAT). Probing depths were within 3 - 4 millimeters. The clinical diagnosis of NP and NAT on #14 eliminated this tooth as the cause of pain and previous swelling. Tooth #15 was clinically diagnosed with pulpal necrosis (PN) with NAT. PA radiographs showed normal bone height and trabeculation with no periapical radiolucency visualized on both tooth #14 and 15 (**Figure 1(a)**). As a definite diagnosis could not be established through conventional methods, more information through a limited field of view (FOV) CBCT of #14 and #15 was obtained.

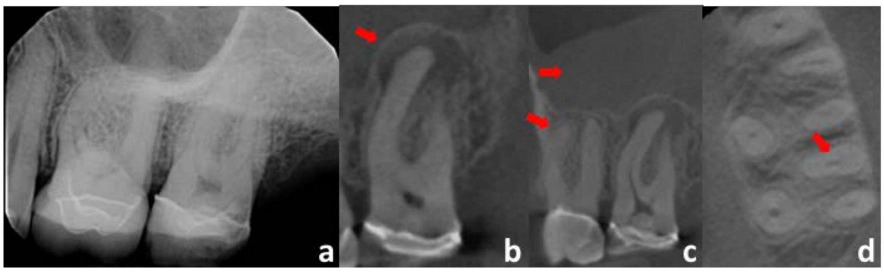

Figure 1. PA radiograph showing normal structures on tooth #13-15 (a); However, sagittal CBCT scan of #15 (b) revealed a periapical lesion elevating the sinus (arrow). Sagittal scan of #14 and #15 (c) showing thickened sinus mucosa (upper arrow) and normal periapical tissue on #14. Axial section showing single, centrally-located MB canal of #15 (d); CBCT was very helpful in diagnosis and canal determination.

In contrast to the PA radiographs, the CBCT results showed a well-defined, non-corticated low attenuation periapical lesion on tooth #15 which was elevating the floor of the maxillary sinus (Figure 1(b)). In addition, moderate mucosal thickening was noted in the partially visualized left maxillary sinus (Figure 1(c)). A radiographic impression of apical periodontitis with moderate mucositis was ascertained on tooth #15. On the other hand, the lamina dura was intact and the periodontal ligament space was uniform around tooth #14 (Figure 1(c)). The buccal and palatal cortices were not thinned, expanded or interrupted. There was no adjacent root resorption or tooth displacement. The trabecular pattern was unremarkable. The mesial buccal root of tooth #15 appeared to have only one canal (Figure 1(d)). The CBCT scans in this case was extremely helpful in diagnosing the odontogenic nature of the patient's pain and swelling, and in preventing unnecessary treatment on tooth #14. Furthermore, the pre-operative determination of the mesio-buccal (MB) root as having only one canal avoided potential additional selective dentin removal which could have been done in attempt to clinically rule out the presence of an MB2 canal.

2.2. Case 2: Non-Odontogenic Diagnosis

A healthy female in her forties was referred for evaluation and treatment due to a periapical radiolucency on tooth #9 (Figure 2(a)). The patient had no symptoms; however, the referring dentist noted a slight swelling on the alveolar mucosa of the tooth. The dentist's findings were confirmed upon clinical examination. Tooth #9 was diagnosed with NP and NAT. There was no history of trauma. A PA radiograph of the tooth showed a circumscribed radiolucency with well-corticated border. A clinical impression of a nasopalatine canal cyst was made and a CBCT was obtained to support the clinical impression and to determine the extent of the lesion. No treatment was recommended for tooth #9.

The CBCT images showed anterior bowing of the nasopalatine canal (Figure 2(b)). The low attenuation, well corticated lesion measured 5.23 mm in its greatest diameter and extended to the buccal cortical plate. There was no thinning, expansion or interruption of the buccal or palatal cortices (Figure 2(c)). The adjacent roots were not displaced or resorbed and were not connected to the

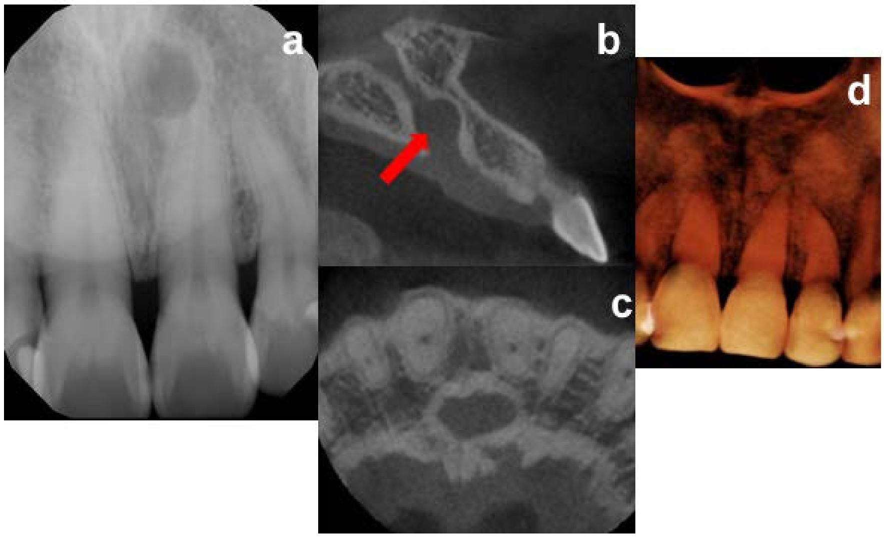

Figure 2. PA radiograph showing tooth #7-10 (a); sagittal (b); axial (c) and coronal (d) CBCT scans of anterior teeth. Arrow on (b) points to a nasopalatine canal cyst seen as PA radiolucency on (a); CBCT confirmed that the lesion was a non-odontogenic nasopalatine canal cyst.

lesion (**Figure 2(c)** & **Figure 3(d)**). With the CBCT results at hand, a consultation with an oral pathologist was made. Surgical excision of the nasopalatine canal cyst with biopsy was recommended. In addition to confirming the diagnosis, knowing the three dimensional extent of the lesion through the CBCT can help clinicians know if a decompression procedure would be indicated, if root canal procedures might be needed due to devitalization of roots in proximity of the lesion and if potential grafting would be needed during the surgery.

2.3. Case 3: Resorption Treatment Planning

A female in her late forties with no significant health history was referred for evaluation and treatment of tooth #8. A circular radiolucency on the cervical area of the tooth presented as an incidental finding upon routine full mouth radiography (**Figure 3(a)**). The patient reported no spontaneous or provoked symptoms associated with the tooth. Upon clinical examination, no blushing, discoloration, probing defect or bleeding were noted. The diagnosis was NP with NAT. The clinical impression for the lesion was external root resorption, which was not seen on the PA radiograph of the same tooth from five years ago. To gather more information, a CBCT was obtained.

There was a well-defined, low attenuation oval area noted in tooth #8 (**Figure 3(b)**). It extended 1.65 mm apical to the crestal bone on the palate to the mid-height of the cingulum and from the periodontal ligament space with no pulpal involvement (**Figure 3(c)** & **Figure 3(d)**). The lamina dura was intact and the periodontal ligament space was uniform. Based on the CBCT findings, the resorptive defect was classified as Heithersay Class 3 with no osseous pathosis [14]. The CBCT offered a better visualization of the defect for the clinician and the patient during the discussions in regards to treatment options and prognosis.

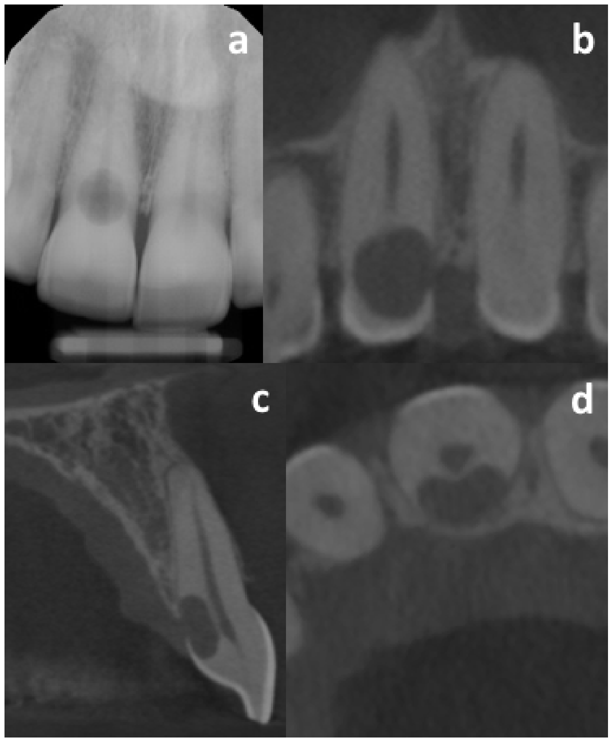

Figure 3. PA radiograph showing tooth #7-10 (a); coronal (b); sagittal (c) and axial (d) CBCT scan of anterior teeth. Detailed view of the external cervical root resorption on CBCT scans (b)-(d), showing no pulpal involvement at this point (c) (d).

2.4. Case 4: Vertical Root Fracture

The succeeding two cases illustrate direct and indirect ways that CBCT scans can help in identifying root fracture. In the first case, a 57-year old female was referred for re-treatment of tooth #19. Her chief complaint was continuous throbbing pain on the left lower quadrant. No significant medical history was noted except for well-controlled hypertension and had good oral hygiene. The patient could not localize the pain and was visibly in distress. The referral letter stated that the RCT on tooth #19 "looked inadequate on PA radiograph". All teeth on the left upper and lower jaw were examined. No caries were noted, several teeth had composite filling with intact margins. Except for tooth #18 and #19, the rest of the teeth was diagnosed with NP. All teeth were diagnosed with NAT. Probing depths were within 3-4 millimeters except in the distal aspect of #18 that had 6mm isolated probing depth. PA radiographs showed normal bone height and trabeculation. No periapical radiolucency was visualized on tooth #18 and 19 (Figure 4(a)). To further investigate the problem, a limited FOV CBCT of #18 and #19 was obtained.

The CBCT results showed no suggestion of periapical pathosis or root fracture on tooth #19. However, there was a well-defined, non-corticated low attenuation J-shaped lesion on tooth #18. The lesion encompassed the entire distal root starting at the crest of the ridge (Figure 4(b), Figure 4(c)). This was not apparent on the PA radiograph. The CBCT findings were consistent with a VRF but an actual fracture could not be appreciated because of the scatter effect from the

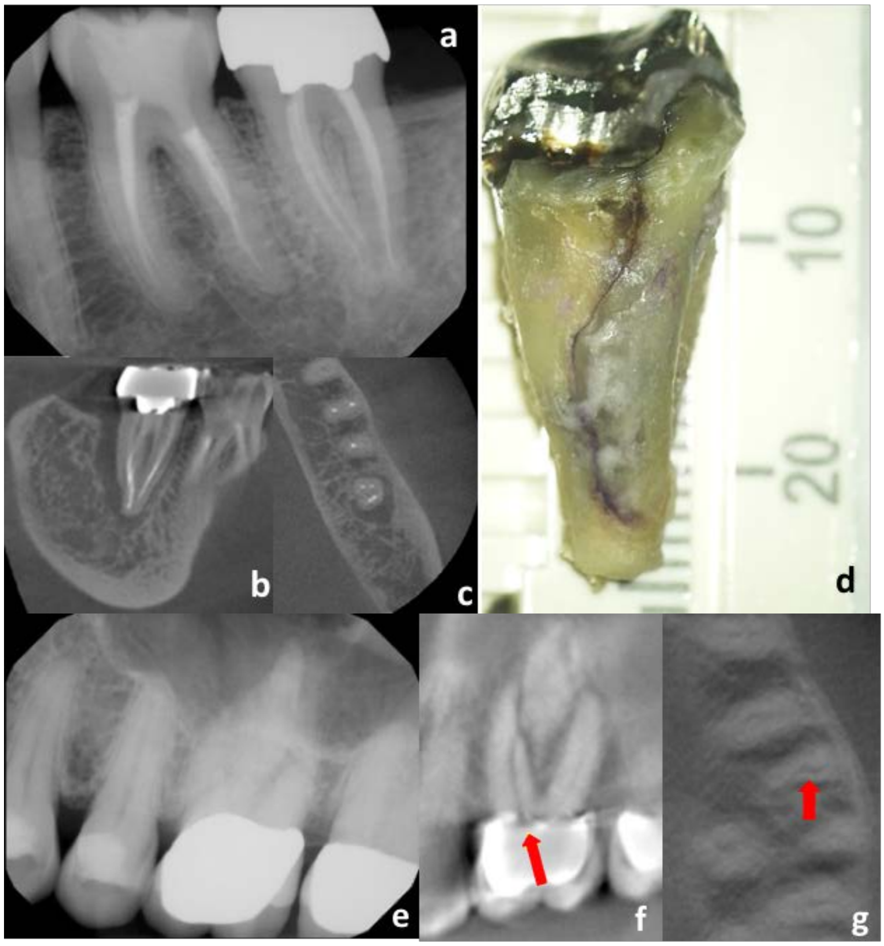

Figure 4. PA radiograph showing tooth #18-20 (a); sagittal and axial CBCT scans of #19 (b & c); distal view of #19 after extraction showing VRF (d); J-shaped radiolucency on distal of #18 was appreciated only on CBCT scans. PA radiograph showing tooth #12-15 (e); Sagittal scan of #14 revealing a VRF on mesial root 9 (f). Axial view of the MB root of #14 showing the fracture line running bucco-lingually.

root canal filling material, among other reasons. No other abnormalities were detected. After a thorough discussion with the patient about treatment options, she chose to have the tooth extracted. A visual inspection of the extracted tooth confirmed the VRF (Figure 4(d)). The patient's symptoms resolved after extraction.

The second case presented with a history of severe pain and swelling on the maxillary left quadrant. The patient had just finished a 7-day course of antibiotic therapy, which relieved the pain and swelling.

Both #13 and #14 did not respond to cold and were diagnosed with symptomatic apical periodontitis (SAP). #12 and #15 tested normal. No probing depth of over 4mm was noted. The PA radiograph did not reveal any significant findings (Figure 4(e)). A CBCT scan was therefore obtained to aid in diagnosis. The sagittal scan showed a vertical root fracture on the mesial root of #14 (Figure 4(f)). The axial view of the scan (Figure 4(g)) showed the fracture line running bucco-lingually. Periradicular radiolucencies were also visible. A definitive diagnosis of pulpal necrosis (PN) was made. Extraction was recommended for this case. No abnormalities were seen on #13.

2.5. Case 5: Complex Anatomy

A healthy 35-year old male was referred for RCT on tooth #20. His general dentist started the treatment, but difficulty in instrumenting the canals was encountered during the procedure. The referral form described the tooth as possibly having more than two canals. The PA radiographs before and during the initial treatment were received from the dentist. The pre-op radiograph showed a "fast break" appearance, wherein the canal disappeared on the radiograph as it continued apically (Figure 5(a)). Fast break occurs when the main canal splits into several small canals that cannot be discernable on a conventional radiograph. The working length radiograph from the dentist appeared to have endodontic files in an asymmetrical distribution inside the tooth, suggesting a missed third canal (Figure 5(b)). A CBCT scan before continuing with the previously initiated root canal treatment was obtained.

As suspected, a third canal on the mesial aspect of the buccal canal was identi-

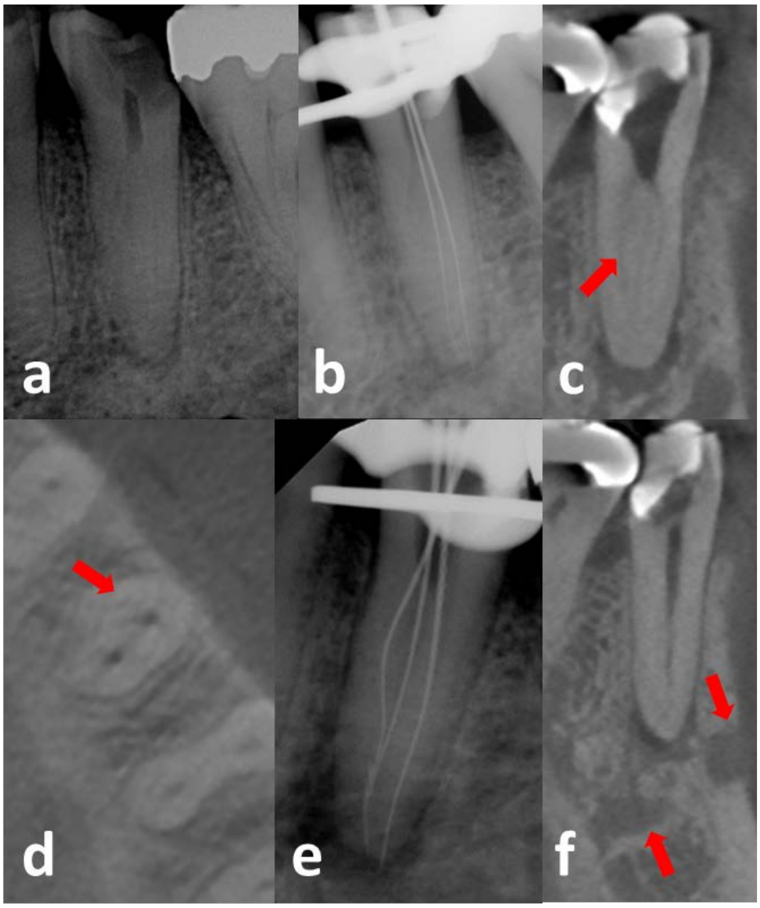

Figure 5. PA radiograph showing full view of tooth #20 exhibiting a fastbreak (a); file shot suggesting a missed third canal (b); sagittal (c) and axial (d) CBCT scan of #20 showing a third canal (arrows), third canal located clinically (e); mental foramen (upper arrow) and IAN (lower arrow (f). Case: Dr. Sam Almassi.

fied in the sagittal (5c) and axial (5d) CBCT scans. These findings facilitated locating and instrumenting the third canal that merged with the mesial canal (Figure 5(e)). The exact location and relationship of the mental foramen and the mandibular canal with the tooth were also determined (Figure 5(f)). In instances when treatment issues due to anatomical variations or uncertainties occur, the use of CBCT proves to be an invaluable service to both the clinician and the patient.

2.6. Case 6: Apical Microsurgery

A 17 year-old male with well-controlled asthma presented for re-treatment of tooth #9. RCT was performed seven years prior due to trauma. From the PA radiograph, tooth #9 had an overextended root canal filling material with a large, circumscribed, low-attenuation area at the periapex (Figure 6(a)). The diagnosis was previously treated (PT) tooth with asymptomatic apical periodontitis (AAP). CBCT was requested for pre-operative apical microsurgery assessment.

The coronal view of the CBCT images revealed a large radiolucency associated

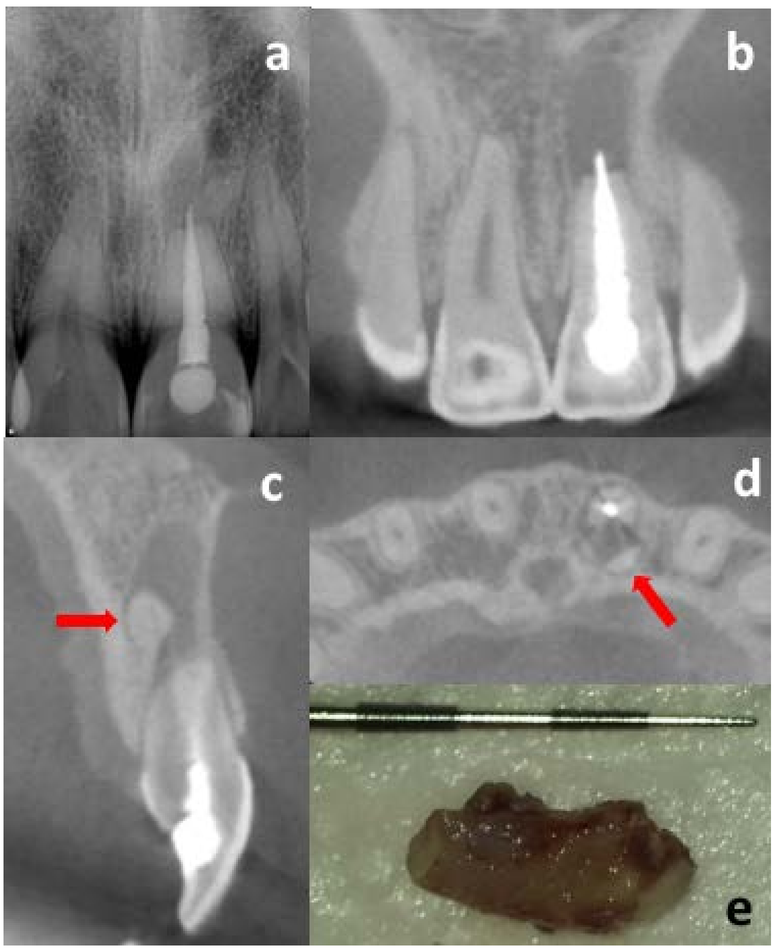

Figure 6. PA radiograph showing tooth #8-10 (a); coronal (b); sagittal (c) and axial (d) CBCT scans of anterior teeth. Fractured root fragment removed during apical microsurgery (e). Arrows on (c) and (d) point to the root fragment in (e) that was only visible on CBCT scan.

with tooth #9 (**Figure 6(b)**). The axial and sagittal sections, however, showed a clear, radiopaque structure disto-lingual to the tooth (**Figure 6(c)** & **Figure 6(d)**). This could not have been possibly visualized using PA radiograph due to superimposition by the tooth and the overfilled root canal obturation material over the structure. Periapical microsurgery was performed. The piece was removed and confirmed to be the fractured fragment of tooth #9 from the trauma (**Figure 6(e)**). The lesion healed after the surgery.

3. Discussion

As illustrated in the cases reported above, the diagnostic value of CBCT has been proven to be its most important use. There is overwhelming evidence that detection rate of apical periodontitis (AP) is higher when assessed with CBCT imaging than with PA radiography. In a meta-analysis report, PA radiographs (digital and conventional) reported good diagnostic accuracy on the discrimination of artificial AP from no lesions, whereas CBCT imaging showed excellent accuracy values [15]. In comparing CBCT imaging with PA radiography, one study found that the detection of apical pathoses is higher when assessed with CBCT imaging (79% probability) than with PA radiography alone (57% probability) [16]. CBCT correctly identified 100% of periapical lesions compared with 24.8% for intraoral radiography [17].

In a clinical study on patients with chronic intraoral pain of over six months, the diagnostic yield of CBCT examination over conventional radiographs to differentiate atypical odontalgia (AO) from symptomatic apical periodontitis (SAP) was tested. The study found that 60% of AO patients had no PA bone destruction [18]. The authors concluded that CBCT improved identification of patients without periapical bone destruction, which may facilitate differentiation between AO and SAP.

The use of CBCT is not limited to detection of AP alone. CBCT was effective and reliable in detecting and quantifying the presence of resorption lesions, vertical root fractures (VRF) and root canals (Case numbers 3, 4, 5); hence it can directly affect treatment planning and prognostication. Compared with intraoral radiography, CBCT had a significantly higher overall sensitivity, diagnostic accuracy and inter-examiner agreement when it was used to assess external and internal cervical resorption [19]. *In-vivo* vertical VRF that could not be visualized on PA radiographs were diagnosed with CBCT [20]. Mesiolingual canals of maxillary molars (MB2) were detected with higher specificity and sensitivity using CBCT than PA radiograph [21]. Not surprisingly, one study found that additional information obtained from CBCT led endodontists to modify their treatment plan in approximately 62% of the cases [22].

In apical microsurgery, pre-operative CBCT can provide very useful information in assessing complex and overlapping anatomical landmarks (e.g. mandibular canal, nasopalatine canal, sinuses) and concealed structures (Case 6), together with their relationship to the tooth to be treated. CBCT is strongly recommended before performing apical microsurgery to localize root apices and to evaluate proximity to adjacent vital anatomical structures [23] [24]. Having detailed knowledge of anatomy before a surgical procedure will help tremendously in treatment planning, in formulating pre-operative strategies and in navigating around critical landmarks, thus minimizing surgical time and complications.

Just like any emerging technology, CBCT does not come without its limitations. The presence of artifacts caused by root canal filling materials resulted in inaccuracies of VRF and MB2 detection by CBCT [21] [25]. It is recommended that when endodontic retreatment is necessary to remove the root filling prior to the CBCT examination. This can help eliminating artifacts, thereby permitting the use of the larger voxel protocol that has good diagnostic performance and lower radiation dose [21]. However, this recommendation may not be practical in instances when CBCT becomes the deciding factor whether retreatment should start or not. Patients may not want to spend additional time, effort and money for exploratory procedures just to remove artifacts for a better scan sensitivity. Further, the PDL space of healthy teeth demonstrates significant variation when examined by CBCT, which can affect radiographic interpretation of healthy and diseased teeth [26].

In 2015, the American Association of Endodontists (AAE) issued an updated joint position statement with the American Association of Oral and Maxillofacial Radiologists (AAOMR) regarding the use of CBCT in endodontic treatment [23]. Both associations discussed important considerations when deciding whether conventional PA radiographs or CBCT should be used in various endodontic procedures such as diagnosis, initial treatment and retreatment, management of complex cases and assessment of outcome. The general message of the joint position paper was to use CBCT only when the need for imaging cannot be met by lower-dose two-dimensional radiography. Furthermore, CBCT should not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. When a CBCT is used, clinicians should also keep in mind that like any new technology, training and experience is critical. Clinicians' experience level is correlated with their ability to correctly diagnose periapical disease in CBCT volumes and the referral to an oral and maxillofacial radiologist should always be considered [27].

4. Conclusion

The preceding cases demonstrate the importance of CBCT in endodontic diagnosis and treatment planning. Clinicians should take advantage of this technology to better serve their patients. However, prudence and good clinical judgment must still be exercised when deciding to utilize CBCT or when translating CBCT interpretation to actual treatment. Weighing potential risks and proven benefits must come hand in hand with excellent diagnostic skills. The ALADA (As Low As Diagnostically Acceptable) principle must always be observed.

Acknowledgements

The authors wish to thank Dr. Sam Almassi (Case 5) of the Advanced Program

in Endodontics, Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, CA, USA.

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