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The Role of 3-D CBCT in Endodontics

John West, DDS, MSD, received his DDS from the University of Washington, where he is an affiliate professor. He is the founder and director of the Center for Endodontics in Tacoma, Wash, and earned his MSD at Boston University, where was honored with the Distinguished Alumni Award. Dr. West and his 2 sons, Drs. Jason and Jordan West, are in private endodontic practice in Tacoma. He can be reached via the email address johnwest@centerforendodontics.com.

Disclosure: Dr. West is co-inventor of ProTaper Gold and WaveOne Gold (Dentsply Sirona Endodontics).

This article discusses the important role that 3-D CBCT technology can play in benefiting both the clinician and the endodontic patient.

INTRODUCTION

In endodontics, we "do it in the dark..."

...Until the endodontic light bulbs were turned on through technological "eye openers!"

Endodontics is the only dental discipline where the dentist cannot simultaneously *see* and *do*. Can you imagine preparing anterior porcelain veneer preps with your eyes closed? Of course not. And yet, this blind dentistry has been asked of us during our entire dental career when performing endodontics. We have been asked to make endodontic radicular preparations that are supposed to be cleaned of all debris and bacteria and filled in 3 dimensions—just like any other cavity preparation, with the exception of one essential ingredient: *direct* vision.

Direct vision in radicular *indirect* situations requires groundbreaking technologies that allow the dentist to more precisely diagnose and treat patients with endodontic disease. In endodontics, light bulbs have been switched on over time, and endodontic clinicians and their patients are benefiting from techniques and equipment that allow dentists to almost *see* and *do simultaneously*.

A Brief History of 6 Endodontic Light Bulb "Eye Openers"

While endodontics does have a number of clinical eye openers, such as SEMs, histology, pathology reports, etc, none allow the dentist to direct and guide simultaneous treatment. There are, however, 6 identifiable eye openers that collectively have allowed dentists to treat with a higher degree of confidence in real time.

1. Operating Microscope: It was the operating microscope that enabled dentists to prepare successful access cavities and achieve the first "F" of predictable endodontics: "Find" all of the canal orifi.[1] While only a handful of courageous endodontists were early adopters and teachers, it was Dr. Gary Carr who is often considered the father of microscope endodontics. In the early to mid-1990s, these early "techy" endodontists began teaching other endodontists and teachers of American graduate endodontic programs. The eventual result of this increased awareness of diagnostic and treatment value was that the American Association of Endodontists (AAE) became an early proponent of training in microscopes for endodontic residents and successfully advocated that the Commission on Dental Accreditation (CODA) include a microscope proficiency standard (4.9.j) to the CODA educational standards for endodontic graduate residency programs in 1998. As a specialty, we have never looked back. General dentists who have mastered the microscope in their endodontics and restorative dentistry have also never looked back.

2. Apex Locators: Apex locators have become accurate and reliable in helping the clinician identify the canal's physiologic terminus. They also encourage accuracy of cleaning to the radiographic terminus while preparing radicular shapes with unparalleled precision to the physiologic terminus without transporting internally through blocking or externally by tearing or frank perforation of the original apical portal of exit (foramen).

3. Tooth Atlas: 3D Tooth Atlas 8 (eHuman) is an excellent source for performing 3-D reconstructions of actual teeth, learning about their similarities as well as their uniqueness, and providing a blueprint for virtual endodontics.

4. Digital Radiography: Digital radiography allows the clinician to instantly see high-resolution radiographs of the root canal system in 2 dimensions. These 2-D radiographs contribute to making the dental diagnosis and are an important tool to measure treatment progress. Because periapical radiographs do not offer a third dimension, dentists have optimized traditional 2-D radiography techniques to overcome that deficiency. Different horizontal and vertical tube shifts, such as the SLOB (Same Lingual, Opposite Buccal) rule, are often used as routine radiographic series. The SLOB rule is used to identify the buccal or lingual location of objects (root canals, impacted teeth, mental and palatal foramina, etc) in relation to a referenced object (usually a tooth). This concept can be confusing at first; how-

ever, here is an easier way to apply it: acquire one image of the area of interest as a reference. Then take a second image of the area, moving the sensor tube head mesially (ie, in the same direction). If the area of interest moves mesially (ie, it follows the tube head), then the object is located on the lingual. If the area of interest moves distally when the tube head moves mesially (ie, in the opposite direction), the object is located on the buccal. With all of these tube-head "tricks," the third dimension is still not archived and the dentists who do not have access to 3-D imaging have to do some guessing. This is never a good thing when delivering dental care!

5. Accurate Radicular Shaping Files: Endodontic shaping file systems, such as ProTaper Gold and WaveOne Gold (Dentsply Sirona Endodontics) and replica NanoFlow gutta-percha cone matches (Dentsply Sirona Endodontics) have given dentists worldwide the confidence that they can treat endodontic patients with consistent, predictable, safe, and no longer "blind" radicular preparations when performing endodontic treatment. A reliable conefit that proves radicular shapes is the dentist's way of validating proper finishing, exactly like it would be for the crown fit before cementation. A dentist would never *assume* a crown fit perfectly, then mix the cement and attempt to seat the crown without first using a try-in. Endodontics is no exception. The clear evidence of conefit gives the dentist confidence that the root canal system is ready for controlled and easy 3-D obturation.

6. Three-dimensional Cone Beam Computed Tomography (CBCT): Conventional film/digital radiographs only provide the clinician with a 2-D image. Though the information provided from periapical radiographs can be enhanced by increasing the image size and with different horizontal and vertical tube shifts and digital filters, such as sharpening, they do not have low sensitivity, specifically regarding the visualization of tooth anatomy and pathology. CBCT imaging technology and 3-D imaging surgical navigation are already a reality and available in multiple surgical sciences, such as ENT and neurosurgery. CBCT allows clinicians to evaluate the area of interest in 3 dimensions with visualization of anatomy without superimposition

Figure 1. Examples of The Role of 3-D CBCT in Endodontic Diagnosis.

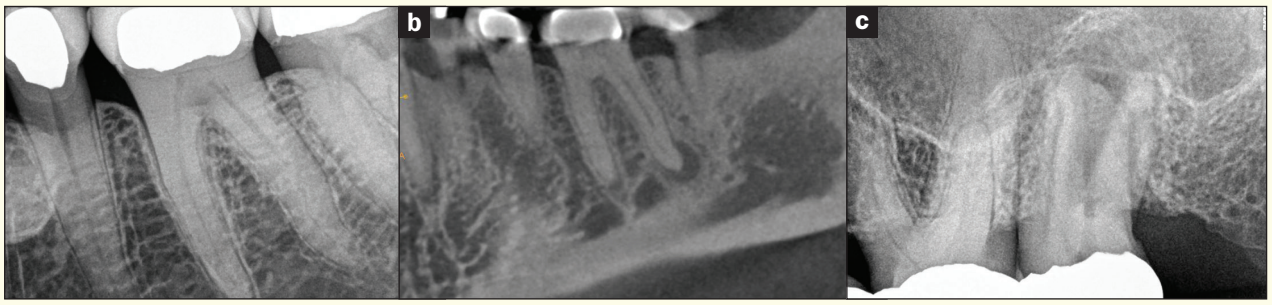

Figure 1a. A pretreatment 2-D image of the author's mandibular first molar, showing an apparently healthy lamina dura and attachment apparatus.

Figure 1b. A pretreatment 3-D image suggesting a distal lesion of endodontic origin (LEO) that was validated by negative pulp testing and an eventual acute alveolar abscess.

Figure 1c. A pretreatment 2-D image of a bite symptomatic of a maxillary left second molar with apparent radicular radiolucencies, but probing was within normal limits, there was no loose crown, it was not in hyperocclusion, and there was no sinus infection.

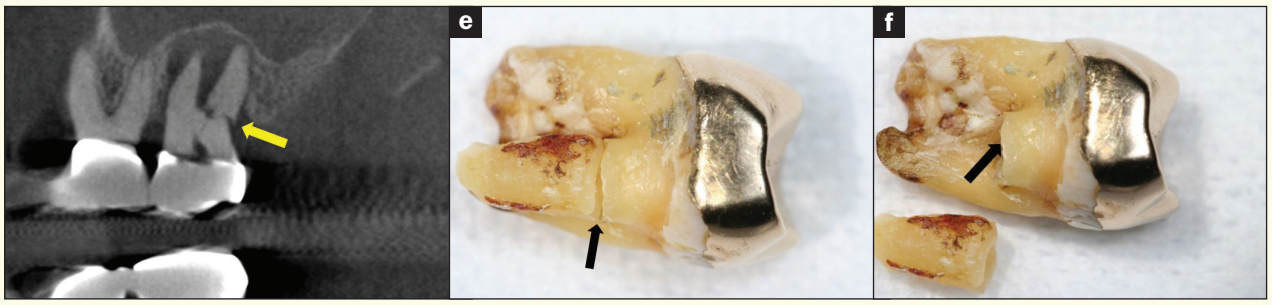

Figure 1d. A pretreatment 3-D image suggests a horizontally fractured DB root and diagnosis.

Figure 1e. An extracted tooth with a horizontal fracture, as indicated by a 3-D image.

Figure 1f. Evidence of a completely fractured DB root and a validation of the diagnosis. The 3-D imaging prevented improper endodontic treatment.

Figure 1g. A pretreatment image of a maxillary left first molar.

Figure 1h. An axial 3-D CBCT view shows no MB2.

Figure 1i. A coronal 3-D CBCT view unravels the pain diagnosis: an accidentally notched MB root of maxillary second molar that occurred during an earlier first molar endodontic surgery.

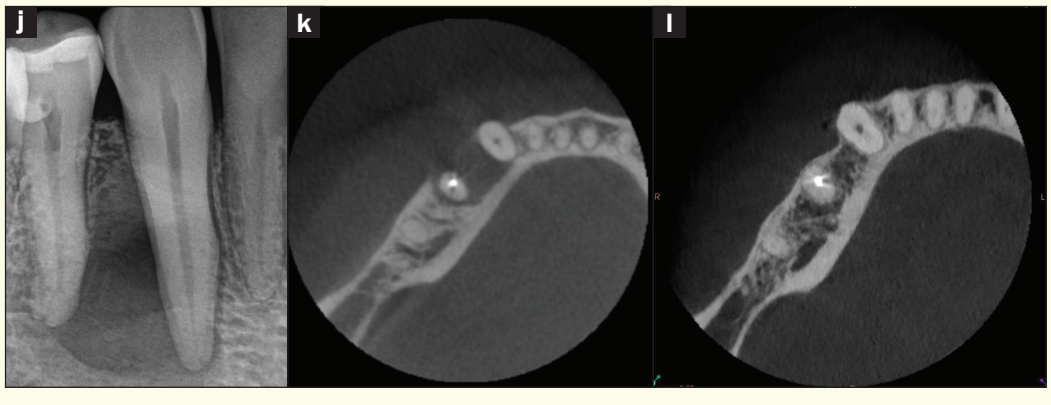

Figure 1j. A pretreatment image of an LEO between the mandibular right cuspid and first premolar.

Figure 1k. An axial 3-D CBCT image at the time of endodontic obturation.

Figure 1l. A 3-D CBCT axial image proving buccal plate repair.

of adjacent structures. The capacity to traverse through a tooth using submillimeter slices before, during, and after treatment results in better diagnosis and greater endodontic precision and produces higher predictability.

There is already evidence of widespread acceptance and application of CBCT technology in endodontic practice.[2-14] My personal survey, in preparation for my 2017 American Association of Endodontists (AAE) presentation, titled "Endodontic Trends: Can Our Past Predict Our Future?," revealed that 55% of endodontists have 3-D CBCT imaging systems installed in their offices. CBCT imaging is actively being used for a variety of endodontic diagnostic and treatment applications. However, in particular, the general comment section of my survey suggested that there is still a gap in acknowledgment of CBCT's usefulness between endodontists. Although some practitioners had major concerns about the benefit for the patient, particularly in regard to radiation exposure, there were also a large number of survey respondents who agreed that CBCT technology can deliver additional information not available from 2-D radiography. However, the benefit-vs-risk ratio should always be in favor of the patient if CBCT scans are considered.

The Role of 3-D CBCT in Endodontics

The best education in the world is your own: "The proof is in the pudding."

Below are 7 real-life examples of the role of 3-D CBCT in endodontics, which include my own personal experience. I have divided the personal examples of my article into early "ah-ha" moments at the Center for Endodontics (Tacoma, Wash) that validated for our 3 partners the value of 3-D CBCT in both endodontic diagnosis and endodontic treatment decisions.

Role of 3-D CBCT in Endodontic Diagnosis: Case Examples (Figure 1)

Case 1. See the pretreatment 2-D image of my own mandibular first molar (Figure 1a). The tooth had hurt to bite for months. My own initial diagnosis was hyperocclusion, so I took the beautiful porcelain molar that master clinician Dr. Frank Spear had made 15 years ago and basically flattened it out—still pain. Again, I made a self-diagnosis, and I thought

Figure 2. Examples of the Role of 3-D CBCT in Endodontic Treatment Decisions.

Figure 2a. A pretreatment 2-D periapical view of a maxillary right central incisor. The arrows point to apical and lateral LEOs.

Figure 2b. A clinical image of a sinus tract presence.

Figure 2c. A sagittal 3-D CBCT view of a facial post perforation.

Figure 2d. A post was removed using a Ruddle Post Removal System (Kerr Dental).

Figure 2e. Flowable composite (Revolution [Kerr Dental]) placed over Geristore (DenMat) perforation repair.

Figure 2f. A one-year post-treatment view of the perforation repair and nonsurgical root canal system retreatment. (Courtesy of Dr. Jordan West, Center for Endodontics, Tacoma, Wash).

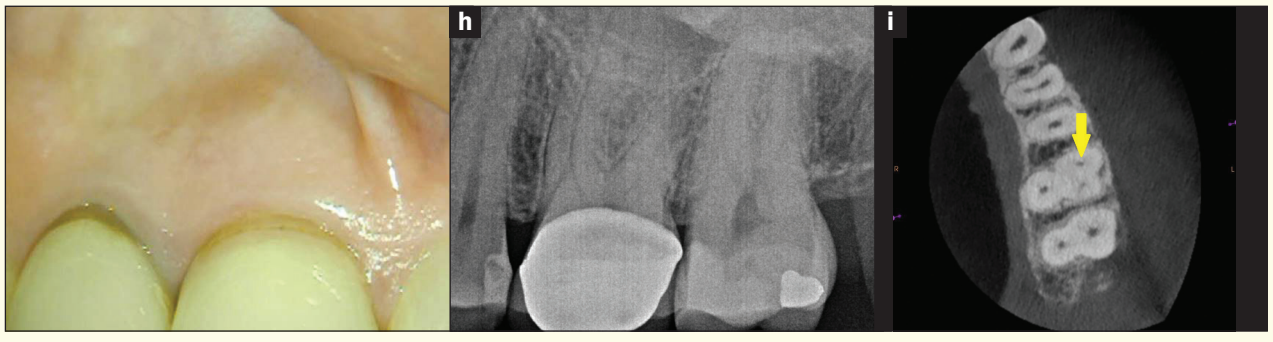

Figure 2g. The closed and healed sinus tract.

Figure 2h. A 2-D periapical pretreatment of a maxillary left first molar.

Figure 2i. An axial 3-D CBCT image showing one MB canal.

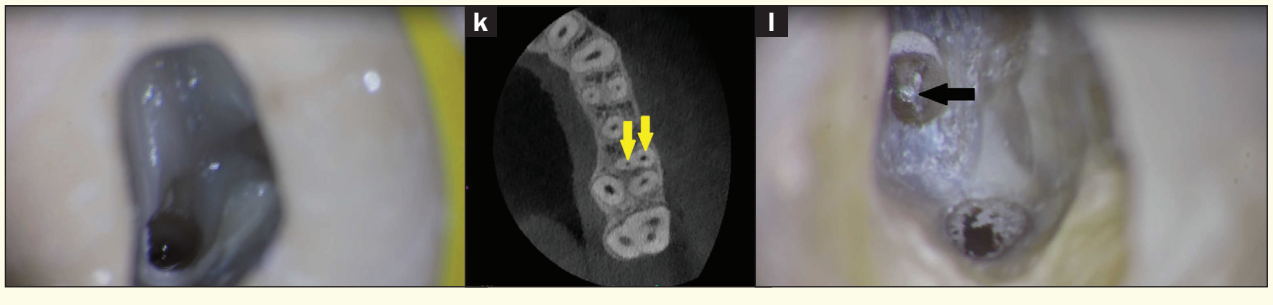

Figure 2j. The one and only MB canal is discovered and treated.

Figure 2k. A 3-D CBCT axial view of a different patient's maxillary left first molar, indicating an MB1 and MB2 were present.

Figure 2l. The MB1 was identified and cleaned, and the presence of an MB2 was found (arrow).

this bite pain felt like dentin pain, so I figured the crown was loose and rubbing on dentin. I tried my best to remove the crown with the GC Pliers (GC America) crown-removing instrument. The crown did not come off, but I think I almost extracted the tooth! After no relief, we took a second PA, and no apparent radicular pathology was observed. Remarkably, endodontics was not on my radar. Perhaps I was in denial; I said, "See, no endo needed." My assistant suggested a 3-D CBCT. The coronal 3-D CBCT slice of my tooth No. 19 told the truth (Figure 1b). The significant apical radicular pathology, not visible on the periapical images, clearly indicated the pulp was probably necrotic, followed by a radiographic lesion of endodontic origin (LEO). Pulp testing validated my nonvital pulp, and, with the correct diagnosis at hand, 3-D endodontic treatment was performed and successfully completed. Gratefully, my symptoms have been gone for a year since treatment, and the LEO has healed. I had misdiagnosed my own tooth! The CBCT showed me the truth. It brought me not only closer to reality—a CBCT hallmark—but actually *to* reality.

Case 2. A patient presented with duplicable pain to bite No. 15. A pretreatment image was taken of tooth No. 15 (Figure 1c). Pulp tests were vital, and probes were within normal limits. It was not a loose crown, hyperocclusion, or sinusitis. So, what is the diagnosis? It could possibly be a radiolucent LEO apical area of the DB root, but it cannot be an LEO since pulps necrose coronally to apically and chamber pulp tests were vital, even to the test cavity: a small access was made into the dentin without anesthesia, and the patient readily felt the dentin. The diagnosis cannot be a lesion of periodontal origin since healthy probings were shown. The diagnosis became clear after a 3-D CBCT of the coronal section revealed a DB root fracture (Figure 1d), which explained the duplicable bite pain, vital pulp, and the absence of a lesion of periodontal origin. It was unrestorable, so an oral surgeon removed tooth No. 15 as well as the fractured DB root (Figure 1e). The DB horizontal root fracture was complete (Figure 1f). The cause was unknown, but perhaps trauma occurred during the extraction of tooth No. 16.

Case 3. See the pretreatment image of a periapical radiograph of a maxillary left first molar (Figure 1g). The patient had pain in the same area, although the tooth had been previously treated both nonsurgically and surgically a number of years before. With the persistent pain, the endodontist suggested removal and replacement or a surgical exploratory. There were *no* symptoms to duplicate, simply pain in the area. I did an anesthetic test. Twice, I anesthetized with a posterior superior alveolar (PSA) nerve block and also infiltrated buccal to tooth No. 14. Pain went away both times. I boosted with long-acting Marcaine, and the pain went away for the several hours the anesthesia was present. The 3-D CBCT imaging showed no MB2 canal or radicular pathology (Figure 1h). When I scrolled through the coronal view, I was able to observe a resorptive type of defect associated with the mesial root of tooth No. 15. In truth, the endodontist had nicked the MB root of tooth No. 15 (Figure 1i) when previously beveling the DB root of tooth No. 14 in preparation for the surgical DB seal! This explained the dull pain relief with anesthesia. Endodontics for tooth No. 15 has been finished and our patient is pain free again! And, again, 3-D CBCT brought us to reality!

Case 4. A pretreatment periapical radiograph demonstrated a large radicular lesion overlapping teeth Nos. 27 and 28 (Figure 1j). Pulp testing proved tooth No. 28's pulp was nonvital and was the point of origin for the large lesion extending to tooth No. 27. Three-dimensional endodontics were performed for tooth No. 28. The axial 3-D CBCT image revealed the true extension and the absence of the buccal cortical plate (Figure 1k). This information is important and is not provided by a 2-D image (Figure 1l). The 6-month postoperative scan demonstrated good healing. This degree of repair was also evident in the 6-month PA, but the healing of the buccal cortical plate could not be accurately measured. The healing of large radicular lesions should be observed in 3-D using axial, coronal, and sagittal planes. This patient demonstrates the importance of 3-D CBCT imaging evaluation of treatment outcomes.

The Role of 3-D CBCT in Endodontic Treatment Decisions: Case Examples (Figure 2)

Case 5. A pretreatment image of a maxillary right central incisor with apical and lateral radiolucencies is shown in Figure 2a. A clinical image of a closed but persistent sinus tract is shown in Figure 2b. The 2-D radiograph and sinus tract suggest an apical undersealed root canal system and possible post perforation on the facial. While the SLOB rule is helpful to identify when post perforation is on the facial, its exact position and tangential tear is more accurately measured using a sagittal 3-D CBCT scan. The gingival crevice probes within normal limits. The sagittal view 3-D CBCT scan proves the post perforation is facial, near the CEJ, and that half of the post resides in the attachment apparatus (Figure 2c). As expected, a tangential perforation tear is observed. Biologically and aesthetically, there was some concern for a surgical approach and gingival healing with a patient who had a high smile line. While a nonsurgical attempt meant risking the crown structure, the patient wanted to take that risk in order to avoid a surgical correction or implant—both of which would have still been a consideration if the nonsurgical seal was not successful. The post was removed using a Ruddle Post Removal System (Kerr Dental) (Figure 2d). Flowable composite was then placed over histologically compatible Geristore (DenMat), and nonsurgical retreatment was finished, courtesy of Dr. Jordan West (Center for Endodontics) (Figure 2e). A periapical image taken at the continued care appointment can be seen in Figure 2f. A one-year continued care clinical image showing the healed sinus tract and the successful radiographic treatment result can be seen in Figure 2g. The nonsurgical vs surgical decision was guided by the 3-D CBCT.

To me, endodontics has never been about what we can get away with but, instead, what we can get. CBCT helps us get what's possible.

Case 6. Most dentists who have performed endodontics within the last decade are aware of the sometimes elusive MB2 canal, specifically in maxillary first molars (Figure 2h). Well-intended dentists often ask, particularly in hands-on workshops, "Where do I look for the MB2, when should I look, and when should I stop looking?" The 3-D CBCT is essential in answering these 3 questions. This periapical 2-D image of a maxillary left molar does not give the dentist the answer he or she needs. The 3-D CBCT does, however, prove only one MB canal is present and is validated by its presence in the middle of the root (Figure 2i). The clinical discovery and shaping of the MB canal is complete, and troughing with ultrasonics or burs should be avoided because the MB2 is *not* there, but a perforation is waiting (Figure 2j). The 3-D CBCT axial view is the roadmap that indicates to search or not to search for the MB2.

Case 7. A 3-D CBCT of another patient's maxillary left molar clearly indicates the presence of an MB2 (Figure 2k). The treating dentist can *know* that the MB2 canal is present and needs to be discovered during the endodontic treatment. After access, the MB1 canal is cleaned and the MB2 canal orifice is clearly identified (Figure 2l).

CLOSING COMMENTS

The positive role of 3-D CBCT in endodontics is unmistakable. CBCT is a way of thinking: "How can I be predictably predictable? How can I help the patient make the right decision of not only 'to treat or not to treat,' but also how to treat?" To me, endodontics has never been about what we can get away with but, instead, what we can get. CBCT helps us get what's possible.

The 7 endodontic case examples presented in this article are but a few examples of how the impact of this technology has influenced my daily practice as well as that of my 2 endodontist colleagues. Since the adoption of this technology in our daily practice routine, every patient we treat benefits from our knowledge, and use, of this new visualization technology.✦

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