Revolutionary Advances in Endodontics, Part 1: CBCT

Wyatt Simons, DDS

This, and all future articles that are presented in multiple parts, are available to our readers at our Web site, dentistrytoday.com.

The practice of endodontics is currently in a period of rapid evolutionary advancement. This article is the first in a 3-part series that will outline the areas of endodontics that have received the most revolutionary improvements. This first article illustrates cone beam computed tomography (CBCT) and its impact on our ability to 3-dimensionally diagnose and treat complex root canal systems. The second article will review the recent advances in disinfection that have brought us closer to our goal of completely disinfecting the root canal system. Finally, the third article in this series will illustrate recent advances in our ability to provide a precise and consistent 3-dimensional (3-D) seal of the entire root canal system from the apex to the cavosurface.

INTRODUCTION

CBCT has enabled the practitioner to evaluate endodontic anatomy and disease in a new way.[1] Adding the third dimension in radiographic evaluation has helped close the gap in radiographic interpretation.[2] Our ability to 3-dimensionally view and manipulate individual anatomy that we encounter in clinical practice has vastly increased our efficacy in diagnosis.[3-5] Furthermore, the ability to render these images at such a microscopic level helps guide successful treatment. This capability to noninvasively and accurately visualize the patient's teeth in such a way is remarkable, considering where we were just 10 short years ago.

Furthermore, the ability to render these images at such a microscopic level helps guide successful treatment.

The following cases provide examples of the impact that CBCT technology is having on improving the success of endodontic diagnosis and treatment.

LESIONS OF ENDODONTIC ORIGIN

CBCT has been paramount in our ability to evaluate and diagnose the presence and extent of endodontic disease.[3-5] The following cases exhibit the benefit that CBCT has to reveal lesions of endodontic origin (LEOs) for the clinician as well as the patient.

Lesions of Endodntic Origin: Case 1

In this case, the general dentist sent the patient to the endodontist for additional evaluation of a possible radiolucency in the lower anterior (Figure 1a). The presence of a lesion was subject to interpretation on the 2-dimensional (2-D) digital image. This interpretive limitation of 2-D images has been well-known for almost 40 years.[6] In this case, comprehensive pulpal testing was also compromised by the patient, who manifested obvious, hyper-

continued on page 98

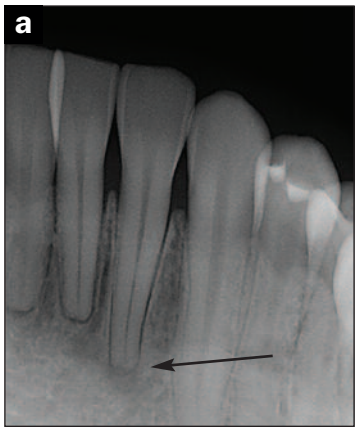


Figure 1a. The digital periapical radiograph leaves the presence of a lesion of endodontic origin open to interpretation.

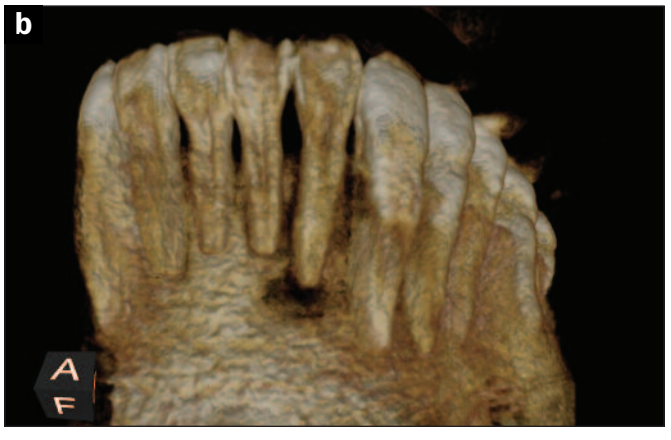


Figure 1b. Three-dimensional (3-D) cone beam computed tomography (CBCT) has the ability to more clearly illustrates the osseous changes present occurring in response to the extension of pulpal breakdown by product's from necrotic tissue into the periradicular tissues.

Figure 2a. A unique location for a radiolucent lesion can be seen on the initial digital periapical radiograph.

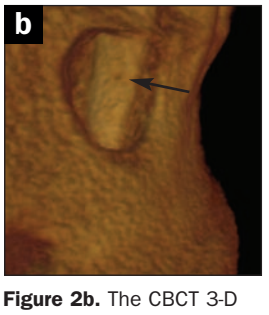


Figure 2b. The CBCT 3-D rendering aided in diagnosis as it clearly illustrated a lateral portal of exit in the center of this osseous defect.

Figure 2c. The lateral portal of exit was instrumented with a sharp *J*-curve of a stiff No. 15 hand file.

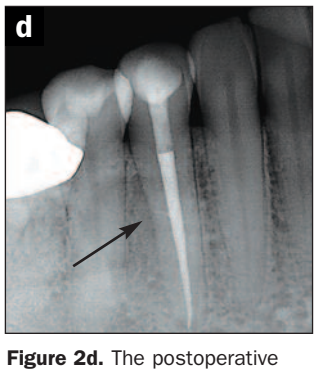


Figure 2d. The postoperative digital radiograph illustrated that the lateral system was sealed.

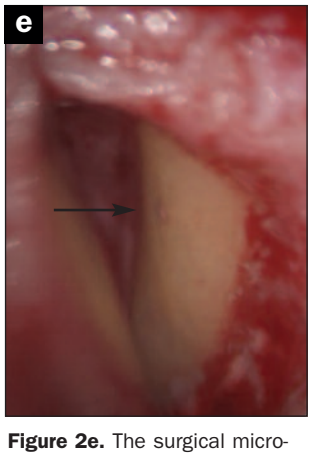


Figure 2e. The surgical microscope directly correlates what was preoperatively noted with CBCT.

Revolutionary Advances...

continued from page 96

sensitive false-positive responses. These limitations in the reliability of our pulpal testings are also well documented.[7,8] The patient and clinician were hesitant to initiate treatment due to the lack in symptoms and absence in other etiologic findings. Upon CBCT evaluation, the presence of the lesion was clearly seen in 3-D (Figure 1b). Hesitation to proceed with treatment was eliminated by the patient and endodontist. The patient was highly motivated to resolve the source of osseous change occurring in her jaw.

Lesions of Endodntic Origin: Case 2

CBCT was valuable in the diagnosis of the unique appearing radiolucent lesion in the following case (Figure 2a). When the patient presented for evaluation and treatment of this radiolucent lesion, comprehensive pulpal testing was done. Tooth No. 28 was verified to be nonvital. Although very suggestive of a lateral LEO, the definitive diagnosis that this lesion's origin was due to extension of endodontic disease emanating from No. 28 was not yet made. The midroot, cystic appearing lesion did not have periapical involvement. Upon CBCT evaluation, a lateral portal of exit could be seen in the center of this osseous defect (Figure 2b). This aided in the diagnosis of a LEO.[9,10] The information granted by the CBCT also impacted the efficacy of treatment as the infected lateral system was more easily located and opened with a sharp *J*-curve of a stiff No. 15 hand file (Figure 2c). We know that the ability to locate and physically instrument intricate areas of the root canal system increases successful disinfection.[11] The postoperative digital image illustrates that the upward facing lateral canal was successfully sealed (Figure 2d). After nonsurgical treatment had been completed, surgical intervention was done due to the appearance and size of the lesion. When the radicular cyst (confirmed histologically) was removed, correlation between what CBCT illustrated preoperatively and what could be visualized directly through the surgical microscope was accomplished (Figure 2e).

MICROFRACTURES

CBCT has greatly helped with the question of the elusive microfracture's presence as well as its extent, both of which are significant factors related to treatment planning. The case below illustrates this challenging question related to a patient that presents with the classic "cracked tooth syndrome."

The patient had intermittent hyperemic sensitivity as well as pain upon release from occlusion. With a 3-D evaluation made possible by CBCT, the clinician can better evaluate the presence and extent of microfractures. In this case, close evaluation of axial slices enabled the clinician to verify that a microfracture was present (Figure 3a). Additional slices suggested that the microfracture was limited to the coronal tooth structure, as there were no signs of osseous changes in the periradicular attachment. After treatment was initiated, the extent of the microfracture was further verified under the microscope (Figure 3b). The successful outcome to eliminate the patient's symptoms and to retain the tooth with full coverage was confirmed at the one-year follow-up appointment (Figure 3c).

VERTICAL ROOT FRACTURES

The following 2 cases illustrate the ability of CBCT to help close the gap in estimating the presence of vertical root fractures (VRF).

Vertical Root Fractures: Case 1

When the patient presented for evaluation of generalized discomfort in the lower right, a 2-D image was taken (Figure 4a). Clinical findings were suggestive of a VRF. However, it was because of the benefit of CBCT that the patient and clinician felt more at ease in proceeding with the extraction of this tooth. CBCT was able to verify and illustrate for the patient the classic 3-D presentation of the changes in surrounding tissue in association with a VRF (Figures 4b and 4c). Upon removal of this hopeless tooth, granulomatous tissue could be seen along the mesiobuccal root (Figure 4d). The VRF was confirmed when the root was scaled for direct assessment (Figure 4e).

Vertical Root Fractures: Case 2

The second VRF case illustrates the ease of CBCT to show a straight buccal VRF. This is an obvious limitation of 2-D radiographs. A digital periapical radiograph was taken when the patient presented with a minor localized swelling near the buccal of tooth No. 28 (Figure 4f). Clinically, the probing and presentation of the periodontal tissues suggested that a VRF was present. However, the patient desired more definitive information before extracting the tooth and losing the long spanning bridge. Initial disassembly was undertaken to both eliminate the post's impact on scatter in CBCT and for initial microscopic evaluation. Upon the post removal, the inter-

continued on page 100

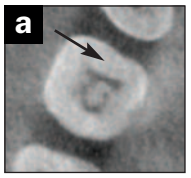


Figure 3a. Axial slice, revealing the presence of a microfracture in the coronal tooth structure.

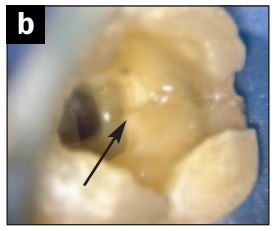


Figure 3b. The surgical microscope was used to verify the extent of the vertical microfracture.

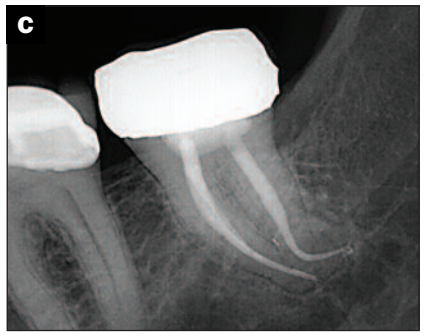


Figure 3c. Successful outcome confirmed at the one-year follow-up.

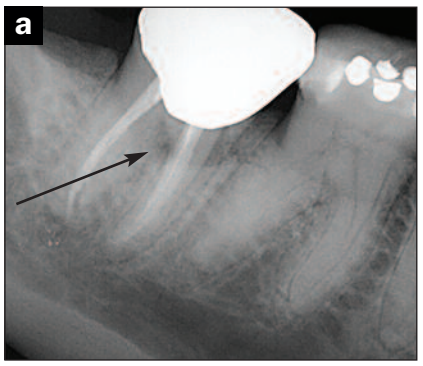


Figure 4a. The digital periapical radiograph revealed likely periodontal involvement.

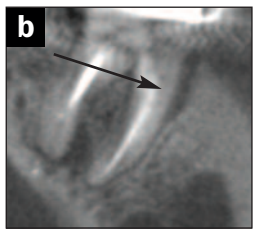


Figure 4b. This sagittal slice more clearly exposes the vertical nature of the defect extending from the coronal aspect of the tooth.

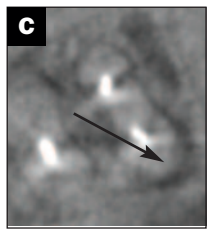


Figure 4c. This axial slice further illustrates the classic presentation of a vertical root fracture (VRF). The localized radiolucency emanates at CEJ.

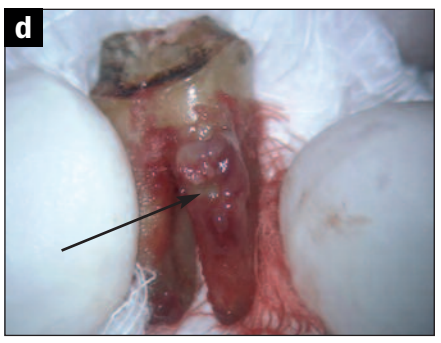


Figure 4d. When the tooth was removed, granulomatous tissue was noted along the mesiobuccal root.

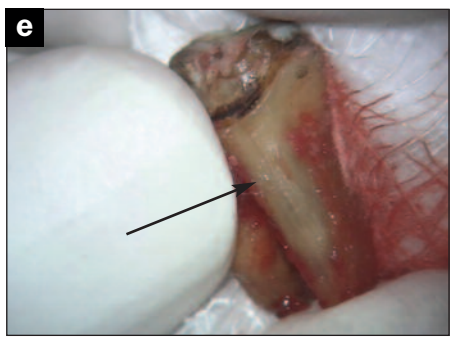


Figure 4e. The VRF can be visualized directly when the root is scaled.

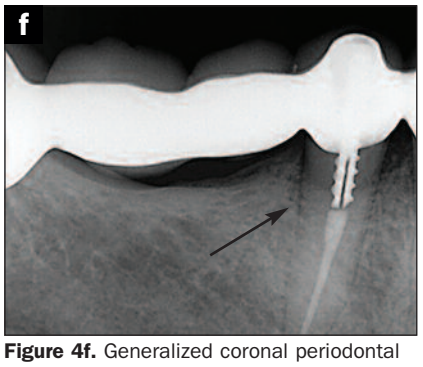


Figure 4f. Generalized coronal periodontal breakdown could be seen on the 2-dimensional (2-D) periapical radiograph.

Figure 4g. Upon initial disassembly, the straight buccal VRF could be visualized through the microscope.

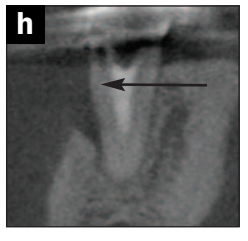
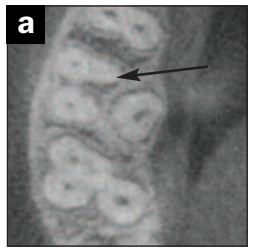
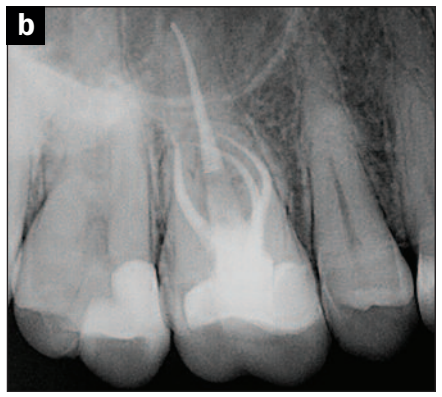


Figure 4h. This frontal slice demonstrates the ease of CBCT to illustrate the buccal bone lose associated with this VRF.





Figures 5a and 5b. With utilization of CBCT, clinicians can confidently and conservatively find and treat the complex anatomy present in the mesiobuccal root of upper molars.

Revolutionary Advances...

continued from page 98

nal extent of a straight buccal VRF was documented through the microscope (Figure 4g). With the use of CBCT, the classic vertical bone loose adjacent to the straight buccal VRF was accurately demonstrated in this frontal slice (Figure 4h). This additional verification appeased the patient's desire to be more certain that the tooth's condition was currently untreatable.

ASSESSMENT OF THE SECOND MESIOBUCCAL CANAL IN MAXILLARY MOLARS

Comprehensive treatment of the entire pulpal system dictates endodontic success.[12] Figures 5a and 5b illustrate the common challenge that arises as the result of a second mesiobuccal system in maxillary molars. It has been shown that 2 canals are present in the maxillary first molar 95% of the time and 93.7% of the time is second molars.[13] Stropko also showed the impact that technology and experience have on our ability to provide comprehensive treatment (ie, the number goes up).[14] When clinicians can visualize complex pulpal anatomy with CBCT, they can confidently and conservatively locate it under the microscope. With utilization of this new technology incomplete endodontic treatment can be a thing of the past.

RESORPTIVE DEFECTS

The ability in accessing the location and extent of resorptive defects has been greatly enhanced with CBCT.[15] The case illustrated here shows the typical dilemma when a 2-D image is sent for assessment of a resorptive defect (Figure 6a). The endodontist is asked by the general dentist to evaluate the resorptive defect and educate the patient about its presence. Ultimately, the objective is to establish an informed treatment plan. CBCT now allows for precise 3-D evaluation of the resorptive defect (Figures 6b and 6c). Here the nature and extent of the lesion can be clearly evaluated and shown to the patient. The well-informed patient is now more knowledgable to make informed decisions about treatment options in regards to his or her dental health. In addition to clearly visualizing the problem present, CBCT aids in patient education when it comes to describing aspects that decrease prognosis.

In this case, the patient wished to push limits and retain the tooth for as long as possible. During root canal treatment, all of the cervically invasive resorptive tissue was removed and MTA was packed to seal the deep, furcal periradicular tissues (Figure 6d). Once time was given for the MTA to set, a flap was raised, the deep MTA was confirmed to be well set, minimal osseous recontouring was done, homeostasis was established, and a composite seal of the cavosurface aspect of the resorptive defect was accomplished (Figure 6e). Periodontal tissues appeared healthy without radiographic signs of further resorption at the 6-month follow-up (Figure 6f).

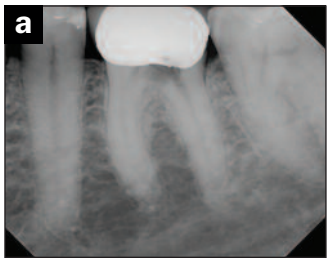


Figure 6a. Comprehensive evaluation of resorptive defects is limited with 2-D radiographs.

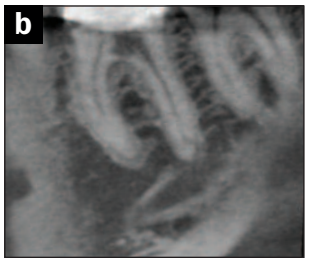


Figure 6b. CBCT allows for a 3-D evaluation of resorptive defects. This sagittal slice aided in assessing the resorptive defect's furcal extent.

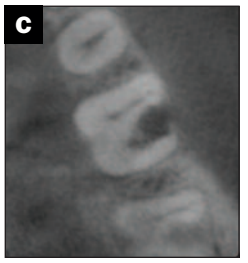


Figure 6c. This axial slice added another dimension of presentation for assessing the extent of the resorptive defect.

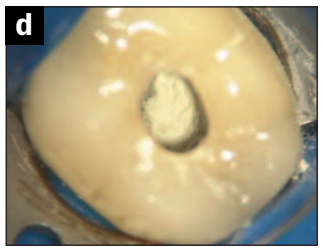


Figure 6d. As part of the nonsurgical endodontic treatment, MTA was packed to seal the deep, furcal periradicular tissues.

Figure 6e. Composite was used to seal the outermost aspect of the root canal system.

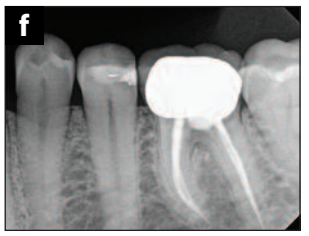


Figure 6f. Six-month recall demonstrated successful retention of the tooth and intact periradicular attachment.

TREATMENT OF MINERALIZED PULPAL SYSTEMS

CBCT has a profound impact on our ability to locate and treat mineralized pulpal systems.[16] Figure 7a illustrates a mineralized molar in need of endodontic therapy. Upon initial microscopic treatment, difficulty in locating the mesiolingual system was encountered. Calcium hydroxide was placed and a CBCT image was taken. The location of the coronally mineralized mesiolingual canal could be seen as patent and at the level of the current conservative exploration but 0.25 mm to the mesiolingual (Figure 7b). Upon microscopic re-entry into the case, the mesiolingual canal was conservatively located and comprehensive treatment was accomplished (Figure 7c).

Figure 7a. Preoperative radiograph of the first molar showing pronounced mineralization of the mesial root.

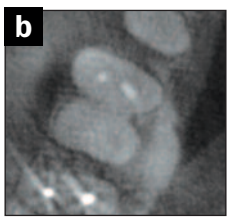


Figure 7b. This axial slice showed the clinician that the mineralized canal was patent at the level of the initial exploration but 0.25 mm to the mesiolingual.

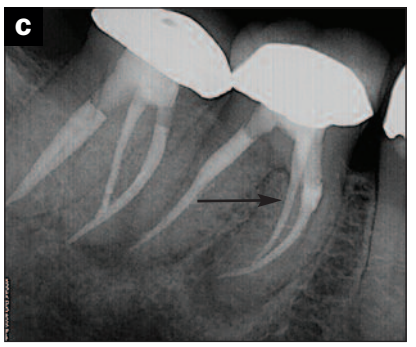


Figure 7c. This area of conservative exploration can be seen on the postoperative radiograph.

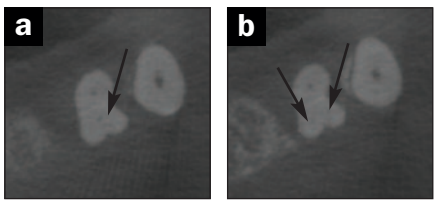


Figure 8a and 8b. Axial slices produced with CBCT. The clinician was able to successfully negotiate the sharp split of the buccal roots in this upper premolar with knowledge gained by this technology.

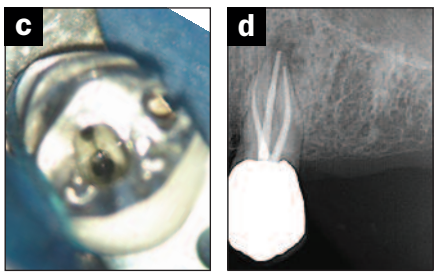


Figure 8c and 8d. Clinical image and postoperative radiograph of the conservative exploration of this complex root canal system.'

In this new era of endodontics, the successes of our outcomes are very visible.

TREATMENT OF COMPLEX PULPAL SYSTEMS

The following case illustrates the benefit of CBCT in directing treatment when complex pulpal systems are encountered in clinical practice. When endodontic treatment was started on the infected maxillary 3-rooted premolar below difficulty was encountered in negotiating the buccal roots. Evaluation of the axial slices enabled the clinician to see how the buccal roots sharply separated (Figures 8a and 8b). It was noted that the canals are separated horizontally over 2.5 mm in less than 0.5 mm. Knowledge of how the canal starts as one and then splits into 2 canals, like a saddle on a horse, directed treatment. With this knowledge, conservative lateral exploration in this fragile area of furcal danger was safely accomplished (Figures 8c and 8d).

CLOSING COMMENTS

CBCT is revolutionizing the specialty of endodontics. Our ability to visualize the vast spectrum of anatomic variations in 3-D has aided in this modern era of endodontics. However, as the old saying goes, "With great power comes great responsibility." In this new era of endodontics, the successes of our outcomes are very visible. There is value in pushing the envelope in all phases of endodontics that may improve successful outcomes so that we remain at the forefront of treatment options available to patients.

The goal of this article was to highlight areas of the endodontic practice that have been significantly impacted by CBCT. However, several areas were not covered. The ability to analyze the location of periradicular anatomical structures of interest such as the sinus and neurovascular structures also holds value particularly in surgery. Existing root canal therapy can better be assessed including missed anatomy, transporta-

continued on page 102

Revolutionary Advances...

continued from page 100

tions, perforations, etc. Another aspect of CBCT that was not shown in this article is the ability to represent anatomical structures without distortion. Accurate measurements can be made because CBCT eliminates angulation errors such as overlapping, foreshortening, and elongating. Finally, it is difficult to illustrate the full benefits of CBCT in this 2-D venue. The benefit of being able to fluidly manipulate these 3-D computerized images cannot adequately be described in this 2-D venue.

The future of CBCT is bright, as many things are possible with this technology.

Future Directions

The future of CBCT is bright, as many things are possible with this technology. Clarity of these images will be enhanced as newer generations of the software improve reconstruction algorithms. This will also assist in current limitations related to scatter. Continued software development will allow for more accurate evaluation of the healing of lesions of endodontic origin through computer-generated alignment of CBCT images. This will enable us to more precisely measure changes in the osseous tissue in a quantitative way. This auto landmark detection for superimposition of images for the comparison of osseous changes will allow us to better monitor successful outcomes. Surgical splints will be constructed from CBCT images and aid in endodontic surgery. Preoperative CBCT images will be able to translate to intra-operative digital images giving valuable information to the clinician during treatment. Continued development in the software will one day allow the clinician to journey down the complexities of individual pulpal systems prior to entering the case clinically. These 3-D annotative models will be generated by CBCT and will be available to the practitioner at the click of a button.✦

References

1. Cotton TP, Geisler TM, Holden DT, et al. Endodontic applications of cone-beam volumetric tomography. *J Endod*. 2007;33:1121-1132.
2. Patel S. New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. *Int Endod J*. 2009;42:463-475.
3. Estrela C, Bueno MR, Leles CR, et al. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. *J Endod*. 2008;34:273-279.
4. Stavropoulos A, Wenzel A. Accuracy of cone beam dental CT, intraoral digital and conventional film radiography for the detection of periapical lesions. An ex vivo study in pig jaws. *Clin Oral Investig*. 2007;11:101-106.
5. Patel S, Dawood A, Mannocci F, et al. Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *Int Endod J*. 2009;42:507-515.
6. Goldman M, Pearson AH, Darzenta N. Endodontic success—who's reading the radiograph? *Oral Surg Oral Med Oral Pathol*. 1972;33:432-437.
7. Fuss Z, Trowbridge H, Bender IB, et al. As sessmentof reliability of electrical and thermal pulp testing agents. *J Endod*. 1986;12:301-305.
8. Petersson K, Söderström C, Kiani-Anaraki M, et al. Evaluation of the ability of thermal and electrical tests to register pulp vitality. *Endod Dent Traumatol*. 1999;15:127-131.
9. Schilder H. Filling root canals in three dimensions. *Dent Clin North Am*. 1967:723-744.
10. Schilder H. Canal debridement and disinfection. In: *Pathways of the Pulp*. St. Louis, MO: Mosby; 1976:111-133.
11. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. *Scand J Dent Res*. 1981;89:321-328.
12. West JD. The relationship between three-dimensional endodontic seal and endodontic failure. Master Thesis. Boston University, 1975.
13. Kulild JC, Peters DD. Incidence and configuration of canal systems in the mesiobuccal root of maxillary first and second molars. *J Endod*. 1990;16:311-317.
14. Stropko JJ. Canal morphology of maxillary molars: clinical observations of canal configurations. *J Endod* 1999; 25:446–450.
15. Cohenca N, Simon JH, Mathur A, et al. Clinical indications for digital imaging in dento-alveolar trauma. Part 2: root resorption. *Dent Traumatol*. 2007;23:105-113.
16. Matherne RP, Angelopoulos C, Kulild JC, et al. Use of cone-beam computed tomography to identify root canal systems in vitro. *J Endod*. 2008;34:87-89.

Dr. Simons received his Doctorate in Dental Surgery from the University of the Pacific, Arthur A. Dugoni School of Dentistry in 1999. He completed his postdoctoral specialty training in the field of endodontics at Boston University in 2001. Dr. Simons does extensive teaching in the field of endodontics, including live patient demonstrations at Signature Specialists, which he founded in 2004. He is a Diplomate of the American Board of Endodontics and he maintains a private practice in San Clemente, Calif. He has published several articles in national and international journals. Dr. Simons holds an adjunctive facility position in the endodontic department at the University of the Pacific, Arthur A. Dugoni School of Dentistry. He can be reached at (888) 905-ROOT or at sigspecialist.com.

Disclosure: Dr. Simons reports no disclosures.