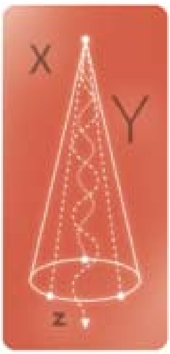
CDA JOURNAL, VOL 38, Nº1



Cone Beam Computed Tomography in the Diagnosis of Dental Disease

SOTIRIOS TETRADIS, DDS, PHD; PAUL ANSTEY, DDS; AND STEVEN GRAFF-RADFORD, DDS

ABSTRACT Conventional radiographs provide important information for dental disease diagnosis. However, they represent 2-D images of 3-D objects with significant structure superimposition and unpredictable magnification. Cone beam computed tomography, however, allows true 3-D visualization of the dentoalveolar structures, avoiding major limitations of conventional radiographs. Cone beam computed tomography images offer great advantages in disease detection for selected patients. The authors discuss cone beam computed tomography applications in dental disease diagnosis, reviewing the pertinent literature when available.

AUTHORS

Sotirios Tetradis, DDS, PHD, is a professor and chair in the Section of Oral and Maxillofacial Radiology at the University of California, Los Angeles, School of Dentistry.

Paul Anstey, DDS, is a diplomate of the American Board of Endodontics and maintains a private practice in Beverly Hills, Calif., specializing in microendodontics and implant surgery.

Steven Graff-Radford, DDS, is the director of The Program for Headache and Orofacial Pain at the Cedars-Sinai Medical Center and an adjunct professor at the University of California, Los Angeles, School of Dentistry.

Periapical, bitewing, occlusal, and panoramic radiographs are used in everyday dental practice to provide valuable diagnostic information in dental disease diagnosis. However, these radiographic projections offer a 2-D representation of 3-D anatomic structures with resultant structure superimposition and unpredictable distortion. This major limitation obscures anatomic conspicuity and poses difficulties in radiographic interpretation during caries, periodontal, oral surgery, and endodontic applications.

Cone beam computed tomography, CBCT, offers an alternative to conventional intraoral and panoramic imaging that circumvents the superimposition and distortion problems. At a significantly lower cost compared to conventional medical CT and utilizing a radiation exposure comparable with other dental radiographic modalities, CBCT provides a true 3-D imaging of the orofacial structures. Although its utilization in dentistry focuses mostly on implant, orthodontic and TMJ evaluation, CBCT technology has potential advantages in common dental disease diagnosis.[1]

During the last decade, an increasing number of CBCT systems have become available. CBCT units can be classified according to the imaged volume or field of view, FOV, as large FOV (6 inch to 12 inch or 15 to 30.5 cm) or limited FOV systems (1.6 inch to 3.1 inch or 4 to 8 cm). In general, the greater the FOV the more extensive the anatomic area imaged, the higher the radiation exposure to the patient, and the lower the resolution of the resultant images. Alternatively, limited FOV systems image only a small area of the face, deliver less radiation and produce a higher resolution image. With the limited FOV CBCT scanners, isotropic voxel resolu-

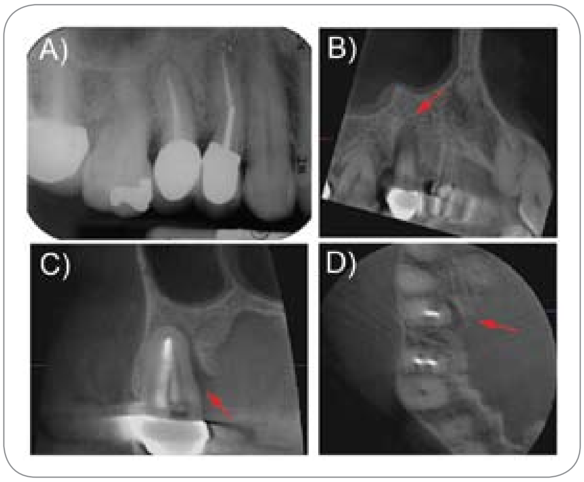


FIGURE 1. Periapical (**A**), sagittal (**B**), cross-sectional (**C**), and axial (**D**) CBCT sections of tooth No. 4. Red arrow on CBCT images points to periodontal defect. CBCT images in this and the remaining figures were generated by the limited FOV 3-D Accuitomo CBCT scanner by J. Morita.

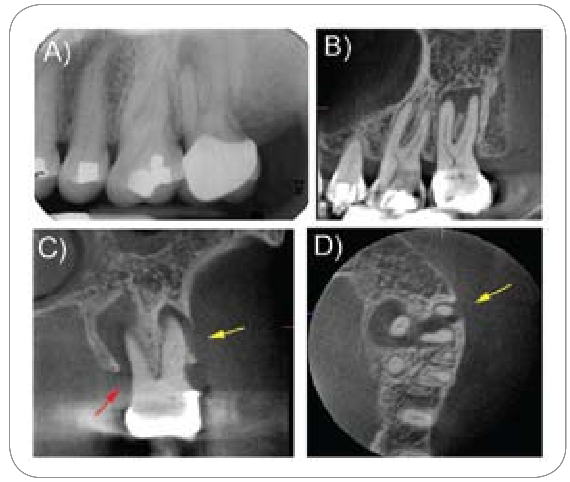


FIGURE 2. Periapical (**A**), sagittal (**B**), cross-sectional (**C**), and axial (**D**) CBCT sections of tooth No. 15. Yellow arrow points to disruption of buccal cortication and red arrow points to periodontal ligament space widening.

tions below 100 µm can be achieved.[2]

Comparative radiation exposure risk from various imaging modalities utilized in dental practice is beyond the scope of the current manuscript. The reader is referred to recent publications comparing effective radiation doses of large, medium, and limited FOV CBCT scanners, medical CT, and conventional intraoral and extraoral radiographs according to the 2007 International Commission on Radiological Protection recommendations.[3,4] An important consideration regarding radiation exposure is that because of the small volume more than one limited FOV scans might be required to examine the whole area of interest, thus increasing the total radiation delivered to the patient.

Applications that do not need highly detailed depiction of structures but require imaging a significant portion of the face, such as for orthodontics or extensive implant reconstruction, could benefit from a moderate to large FOV CBCT scan. Alternatively, applications that require imaging of a small part of the orofacial complex are more appropriately imaged by a limited FOV CBCT system. Typically, dental disease diagnosis falls in the second category. The CBCT parameters should be chosen such that the highest resolution scan can be obtained. This will not only limit patient radiation exposure, but more importantly will provide appropriate diagnostic detail for periodontal and endodontic applications.[5]

In the subsequent sections, the authors review CBCT use for the diagnosis and treatment planning of common dental disease such as caries detection, periodontal evaluation, endodontic applications, tooth impaction, root resorption, and trauma to the teeth.

Caries Detection

Studies comparing the caries detection efficacy of CBCT versus conventional modalities, such as bitewing and periapical intraoral radiographs, are inconclusive. CBCT is reported to more accurately assess proximal caries depth compared to film or storage phosphor periapical radiographs.[6] In a similar study of noncavitated teeth, a large FOV CBCT performed poorer in detection of caries, while a limited CBCT had higher sensitivity only for occlusal caries compared to digital or conventional periapical radiographs.[7] Finally, no difference in the detection of a carious lesion between a limited CBCT and film in proximal premolar surfaces was observed.[8]

Although these and similar reports outline the potential benefit of CBCT technology in caries detection, they are performed in well-controlled experimental settings that do not reflect the reality of everyday dental practice. Beam hardening artifacts are frequent in the imaging of dental structures and particularly tooth crowns.[2] Such artifacts originate from metallic restorations, implants, endodontic restorative material, or other dense objects and create distortion of structures, streaks of bright and dark bands and noisy projection reconstructions that project over adjacent teeth and render diagnosis difficult or unfeasible. In particular, the dark bands may convey the false impression of recurrent caries. Patient movement decreases structure sharpness and definition, and further complicates these artifacts. It has been the authors' experience that at the present time, CBCT technology is not practical or advantageous over intraoral radiography for caries detection. However, if a CBCT scan is taken for other purposes, all teeth present in the imaging volume, should be evaluated for coronal integrity and pathosis.

Periodontal Evaluation

Interdental bone levels can be assessed with conventional radiographs. However, little information can be gained when buccal, lingual, or fractional periodontal bone height needs to be determined because of superimposition of the alveolar bone with the teeth or roots. Furthermore, partial loss of interdental bone thickness can be difficult to determine on 2-D radiographs. CBCT imaging, by allowing the 3-D evaluation of the periodontal tissues, solves these projection problems of periapical and bitewing radiographs.

Indeed, CBCT performs superiorly in the assessment of artificial buccal or lingual periodontal defects compared to periapical radiographs. However, the two modalities behaved similarly in the detection of interdental bone level.[9] When assessing periodontal bone in dry skulls, CBCT provides better diagnostic and quantitative assessment of periodontal defects compared to periapical radiographs. CBCT is particularly advantageous for the buccal and lingual, as well as furcational assessment of periodontal defects.[10,11] These in vitro findings translate to the clinical setting where CBCT outperformed intraoral radiography in precision and accuracy for the detection of periodontal bone levels following regenerative periodontal therapy.[12] The high agreement of CBCT with surgical measurements prompted the authors to suggest that CBCT may replace surgical re-entry as a technique for assessing regenerative therapy outcomes.

The superior ability of CBCT imaging to evaluate periodontal bone levels can be appreciated in **FIGURE 1**. Although on the periapical radiograph (**FIGURE 1A**) periodontal bone levels around tooth No. 4 appear to be relatively normal, CBCT imaging reveals a deep avertical defect extending from the lingual alveolar crest to the apex of No. 4 (**FIGURES 1-D**).

Periapical Disease

Similar to periodontal disease, the ability of CBCT imaging to bypass anatomic structure superimposition and evaluate the teeth and their supporting structures three-dimensionally is advantageous for detecting periapical disease presence and severity.

CBCT showed improved sensitivity, positive and negative predictive values, and diagnostic accuracy compared to conventional radiographs in experimental periapical lesions in pig and human jaws, and in 888 consecutive patients.[13-15] In a patient study including 74 posterior maxillary and mandibular teeth with a total of 156 roots, CBCT detected 34 percent more periapical lesions compared to periapical radiographs and demonstrated, with higher frequency, periapical lesion expansion into the maxillary sinus, thickening of the sinus mucoperiosteal lining and the presence of untreated root canals.[16] In a similar study of 46 teeth with periapical lesions, the increased CBCT sensitivity for disease detection led to the uniform observer agreement that in 70 percent of the cases, CBCT images provided clinically relevant additional information not detected in periapical radiographs, including improved root and root canal visualization, lesion localization, and relation to vital anatomic structures. The same authors also noted that beam hardening artifacts from endodontic restorative material can distort image quality and create diagnostic difficulties.[16]

FIGURE 2 demonstrates the advantages of CBCT imaging in evaluating the status of periapical tissues. The periapical radiograph (**FIGURE 2A**) clearly demonstrates radiolucency at the apex of No. 15 mesiobuccal and distobuccal roots. However, the palatal root cannot be clearly seen due to slight distortion, and the superimposition of the roots and zygomatic process of the maxilla. Sagittal (**FIGURE 2B**), cross-sectional (**FIGURE 2C**) and axial (**FIGURE 2D**) sections clearly depict the extent of periapical disease around all three roots. Furthermore, these sections demonstrate disruption of the buccal cortex suggesting possible fistula formation (C&D yellow arrows), and widening of the periodontal ligament space at the palatal surface of the palatal root suggesting formation of an endo-perio lesion (red arrow).

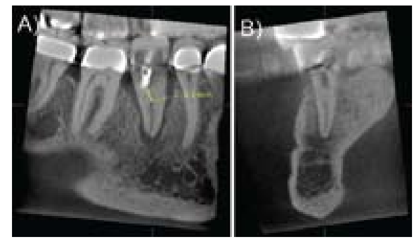


FIGURE 3. Sagittal (**A**) and cross-sectional (**B**) images of tooth No. 29 demonstrate the location of canal opening in relation to existing restorative material.

In addition to improved diagnostic accuracy, limited field of view CBCT imaging demonstrates an increased ability to detect and localize anatomic features of the root and root canal system that can affect treatment planning. CBCT more accurately identified root canals compared to digital periapical radiographs. Interestingly, observers utilizing digital periapical radiographs failed to identify one or more root canals in 40 percent of teeth examined. The authors suggested that in these cases, the failure to identify root canals can result in a less optimal healing outcome.[17] Additionally, CBCT produces accurate measurements of root angulation, compared to conventional imaging, and can be used for the evaluation of root curvature.[18,19] **FIGURE 3** demonstrates CBCT images of No. 29 with a partially calcified canal. Although initial access of the canal opening was unsuccessful, CBCT sections provided useful information for angulation and distance of the canal opening that allowed canal identification.

Root Resorption

Although no experimental or clinical studies have evaluated its usefulness in diagnosing external or internal tooth resorption, several case reports demonstrate the advantage of CBCT technology over conventional radiographs not only

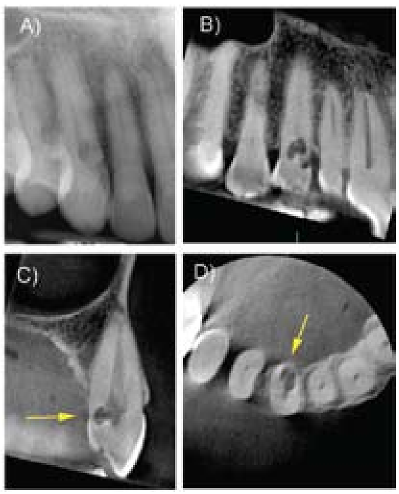


FIGURE 4. Panoramic radiography **(A)**, sagittal **(B)**, cross-sectional **(C)**, and axial **(D)** CBCT sections of tooth No. 27 demonstrate the presence and severity of external (red arrow) and internal root resorption. Yellow arrow points to the extension of internal resorption to the lingual tooth surface.

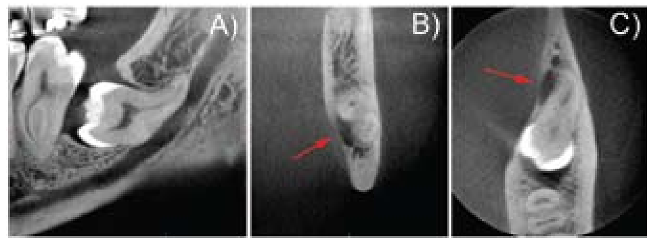


FIGURE 5. Sagittal **(A)**, cross-sectional **(B)**, and axial **(C)** CBCT sections of impacted tooth No. 17. Red arrow points to the lingual position of the inferior alveolar canal.

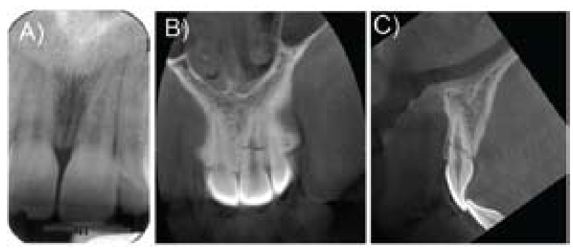


FIGURE 6. Periapical radiograph **(A)**, sagittal **(B)**, and cross-sectional **(C)** CBCT images of tooth No. 9.

in detecting but further in evaluating the extent of resorption.[20-23] There is general agreement that CBCT provides valuable information allowing the exact localization and extent of tooth resorption, as well as possible perforation and communication with the PDL space.[21,24] The authors' experience with many internal and external root resorption cases is in agreement with that assessment. The authors further found CBCT imaging advantageous in the diagnosis, assessment of prognosis, treatment planning, and treatment follow-up of external and internal resorption cases. In the authors' view, limited FOV CBCT is a technological breakthrough in the management of these types of cases.

FIGURE 4 shows a periapical radiograph and CBCT sections of tooth No. 6. On the periapical radiograph internal resorption of No. 6 can be seen. However, the extent and location of the resorption cannot be determined. CBCT sections demonstrate internal root resorption that has eroded a significant part of the tooth toward the lingual aspect of the cervical area. However, the resorption has not perforated the lingual tooth surface (yellow arrow). Lack of perforation supports a favorable outcome in this case after endodontic intervention.

Tooth Impaction

CBCT technology offers clear advantages over conventional radiography for the evaluation of impacted teeth. CBCT demonstrates great usefulness in localizing maxillary canine impaction, evaluating canine angulation and determining resorption of adjacent lateral and central incisors.[25,26] Root development, relation to vital anatomic structures including the inferior alveolar canal, IAC, maxillary sinus and adjacent teeth, the 3-D orientation of the impacted tooth within the alveolus and the detection of any associated pathosis that might cause the impaction can be more accurately determined by CBCT imaging.[27,28] **FIGURE 5** demonstrates CBCT images of impacted No. 17. The close relation of the roots with the inferior alveolar canal, which is positioned lingually to the roots (red arrow), can be appreciated in detail.

Although CBCT scans provide a more precise assessment of tooth impaction, not all impacted teeth require CBCT imaging for diagnosis and treatment planning. It is argued that in the great majority of cases, the relation of the IAC with the roots of impacted mandibular third molars can be evaluated by conventional radiographs. If such films reveal an intimate relationship between the IAC and the roots, CBCT imaging can provide important information for the management of the impacted tooth.[29]

Dental Trauma

One of the more difficult diagnostic tasks in dentistry is dental trauma evaluation. Minimal fracture fragment displacement, structure superimposition, soft-tissue swelling, and the presence of foreign objects can complicate the appearance of tooth fracture in conventional radiographs. Unless the X-ray beam is oriented through the plane of the fracture it may not be possible to separate the fractured root fragments. Furthermore, obtaining good quality intraoral radiographs can be challenging in noncooperative patients.

CBCT imaging is clearly advantageous over conventional radiography for the evaluation of trauma and suspected root

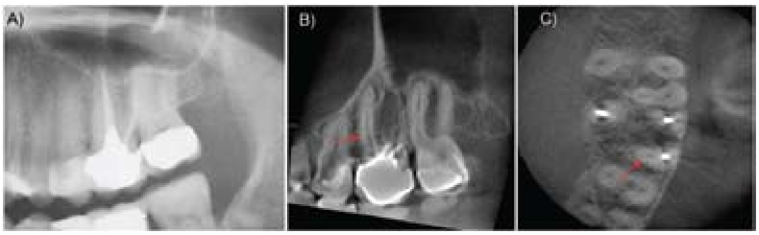


FIGURE 7. Panoramic radiograph **(A)**, sagittal **(B)**, and axial **(C)** CBCT sections of tooth No. 14. Red arrow points to the unfilled canal in the mesio-buccal root of tooth No. 14.

fractures.[30,31] CBCT shows increased sensitivity and greater interobserver variability over conventional periapical radiographs in the detection of experimentally induced horizontal root fractures of central and lateral human incisors. Interestingly, the specificity of both modalities was similar.[32] Additionally, CBCT is statistically significantly more accurate than periapical radiographs in fracture detection of 20 patients with suspected root fractures.[33] **FIGURE 6** illustrates a case where limited FOV CBCT imaging provided central information for the definitive diagnosis of tooth No. 9 root fracture. Periapical radiograph of No. 9 (**FIGURE 6A**) is inconclusive, while sagittal (**FIGURE 6B**) and cross-sectional (**FIGURE 6C**) CBCT images clearly demonstrate the oblique root fracture through the whole root thickness.

Dental Treatment Complications

The authors are not aware of any clinical or experimental studies that have addressed CBCT usefulness in dental treatment complications. However, in the authors' experience, CBCT imaging can prove valuable in cases where a patient's symptoms persist despite appropriate intervention or in cases where a patient develops adverse symptomatology, such as paresthesia, anesthesia, pain, or loss of function. The ability of CBCT to capture the 3-D relation of teeth to anatomic structures such as the inferior alveolar canal, mental foramen/anterior loop, maxillary sinus, restorative materials, dental implants, and other areas of pathosis without any superimposition artifacts, can reveal crucial diagnostic information not available in conventional radiographs.

FIGURE 7 illustrates a case of an endodontically treated tooth No. 14. Although the dentist felt that the endodontic treatment was successful and the panoramic (**FIGURE 7A**) and periapical (not shown) radiographs were unremarkable, the patient complained of persistent pain. CBCT sagittal and axial sections demonstrated the existence of an unfilled second canal in the mesiobuccal root of No. 14 (red arrows).

Importantly, a periapical radiolucency indicative of persistent periapical disease is seen at the apex of the mesiobuccal root. In **FIGURE 8**, radiographs of a patient who developed pain after an endodontic treatment of tooth No. 18 are shown. Periapical radiograph (**FIGURE 8A**) demonstrated endodontic cones significantly extruding past the radiographic apices of both the mesial and distal roots of No. 18. Although the inferior alveolar canal appears to be in close proximity to the apices of No. 18 roots and to the extruded material, the exact relationship of these structures could not be evaluated on conventional radiographs. CBCT images demonstrated that the endodontic cone perforated the roof and extended to the floor of the inferior alveolar canal at the center of the canal (red arrow, **FIGURES 8B-D**). The endodontic cone in the mesial root was located on the buccal of the inferior alveolar canal (yellow arrow, **FIGURE 8D**). Also note persistent periapical radiolucency around the apex of the mesial root of No. 18 seen on periapical and CBCT images.

Conclusions

Over the last decade, CBCT imaging has revolutionized oral and maxillofacial imaging. CBCT technology finds utilization not only in implant and orthodontic applications, but almost in every facet of clinical dentistry. When CBCT scanning is considered, the smallest volume that will image the area of interest should be selected. This will provide higher resolution and lower patient radiation exposure. The ability of CBCT to visualize the 3-D relation of anatomic structures and dental pathology improves diagnosis and treatment planning.

To the best of the authors' knowledge, clear guidelines and evidence-based selection criteria for CBCT utilization have not been established thus far. Based on the published literature and the authors' personal experience, they believe the majority of patients are appropriately managed utilizing conventional radiographs. However, CBCT imaging can be greatly beneficial in diagnosing and treatment planning of select dental patients.

The authors found no indication for CBCT use in caries detection. In cases where periodontal surgery is considered, CBCT provides valuable qualitative and quantitative assessment of periodontal defects. When periodontal or periapical disease cannot be clearly confirmed on periapical radiographs, but is highly suspected based on patient symptomatology, CBCT imaging could be a great diagnostic aid. Additionally, if conventional radiographs suggest anatomic variants such as root curvature or accessory canals, CBCT scans can facilitate accurate assessment and endodontic treatment planning. In most external and internal root resorption cases, CBCT provides valuable information as to whether treatment of these lesions can lead to a favorable outcome.

FIGURE 8. Periapical radiograph **(A)**, sagittal **(B)**, cross-sectional **(C)**, and axial **(D)** CBCT sections of tooth No. 18. Red arrow points to the endodontic cone in the distal, while yellow arrow points to the endodontic cone in the mesial root of No. 18.

Impacted teeth in close proximity to vital structures are accurately evaluated by CBCT imaging. Dental trauma can be a very challenging diagnostic task. When conventional radiographs are inconclusive, CBCT can add valuable diagnostic information in suspected root fractures.

Finally, suspected dental treatment complications can be assessed and corrective interventions, if necessary, can be promptly designed. The treating dentist should determine whether the diagnostic benefits gained by CBCT imaging exceed the patient's risk from increased radiation exposure as well as the financial cost. ■■■■

REFERENCES

1. Tyndall DA, Rathore S, Cone beam CT diagnostic applications: caries, periodontal bone assessment, and endodontic applications. *Dent Clin North Am* 52(4):825-41, vii, 2008.
2. Scarfe WC, Farman AG, What is cone-beam CT and how does it work? *Dent Clin North Am* 52(4):707-30, v, 2008.
3. Ludlow JB, Davies-Ludlow LE, White SC, Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. *J Am Dent Assoc* 139(9):1237-43, 2008.
4. Ludlow JB, Ivanovic M, Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 106(1):106-14, 2008.
5. Farman AG, Field of view. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 108(4):477-8, October 2009.
6. Akdeniz BG, Grondahl HG, Magnusson B, Accuracy of proximal caries depth measurements: comparison between limited cone beam computed tomography, storage phosphor and film radiography. *Caries Res* 40(3):202-7, 2006.
7. Haiter-Neto F, Wenzel A, Gotfredsen E, Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions. *Dentomaxillofac Radiol* 37(1):18-22, 2008.
8. Tsuchida R, Araki K, Okano T, Evaluation of a limited cone beam volumetric imaging system: comparison with film radiography in detecting incipient proximal caries. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 104(3):412-6, 2007.
9. Misch KA, Yi ES, Sarment DP, Accuracy of cone beam computed tomography for periodontal defect measurements. *J Periodontol* 77(7):1261-6, 2006.
10. Mol A, Balasundaram A, In vitro cone beam computed tomography imaging of periodontal bone. *Dentomaxillofac Radiol* 37(6):319-24, 2008.
11. Vandenberghe B, Jacobs R, Yang J, Detection of periodontal bone loss using digital intraoral and cone beam computed tomography images: an in vitro assessment of bony and/or infrabony defects. *Dentomaxillofac Radiol* 37(5):252-60, 2008.
12. Grimard BA, Hoidal MJ, et al, Comparison of clinical, periapical radiograph, and cone beam volume tomography measurement techniques for assessing bone level changes following regenerative periodontal therapy. *J Periodontol* 80(1):48-55, 2009.
13. 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* 11(1):101-6, 2007
14. Patel S, Dawood A, et al, Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *Int Endod J* 42(9):831-8, September 2009.
15. Estrela C, Bueno MR, et al, Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. *J Endod* 34(3):273-9, March 2008.
16. Low KM, Dula K, et al, Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. *J Endod* 34(5):557-62, 2008.
17. Matherne RP, Angelopoulous C, Use of cone beam computed tomography to identify root canal systems in vitro. *J Endod* 34(1):87-9, 2008.
18. Estrela C, Bueno MR, et al, Method for determination of root curvature radius using cone beam computed tomography images. *Braz Dent J* 19(2):114-8, 2008.
19. Peck JL, Sameshima JT, et al, Mesiodistal root angulation using panoramic and cone beam CT. *Angle Orthod* 77(2):206-13, 2007.
20. Patel S, Dawood A, The use of cone beam computed tomography in the management of external cervical resorption lesions. *Int Endod J* 40(9):730-7, 2007.
21. Cotton TP, Geisler TM, et al, Endodontic applications of cone-beam volumetric tomography. *J Endod* 33(9):1121-32, 2007.
22. Maini A, Durning P, Drage N, Resorption: within or without? The benefit of cone beam computed tomography when diagnosing a case of an internal/external resorption defect. *Br Dent J* 204(3):135-7, 2008.
23. Patel S, Kanagasingam S Pitt Ford T, External cervical resorption: a review. *J Endod* 35(5):616-25, 2009.
24. Patel S, New dimensions in endodontic imaging: part 2. Cone beam computed tomography. *Int Endod J* 2009.
25. Liu DG, Zhang WL, et al, Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 105(1):91-8, 2008.
26. Walker L, Enciso R, Mah J, Three-dimensional localization of maxillary canines with cone beam computed tomography. *Am J Orthod Dentofacial Orthop* 128(4):418-23, 2005.
27. Tamimi D, ElSaid K, Cone beam computed tomography in the assessment of dental impactions. *Semin Orthod* 15(1):57-62, 2009.
28. Mah J, Enciso R, Jorgensen M, Management of impacted cuspids using 3-D volumetric imaging. *J Calif Dent Assoc* 31(11):835-41, November 2003.
29. Flygare L, Ohman A, Preoperative imaging procedures for lower wisdom teeth removal. *Clin Oral Investig* 12(4):291-302, 2008.
30. Cohenca N, Simon JH, et al, Clinical indications for digital imaging in dentoalveolar trauma. Part 2: root resorption. *Dent Traumatol* 23(2):105-13, 2007.
31. Cohenca N, Simon JH, et al, Clinical indications for digital imaging in dentoalveolar trauma. Part 1: traumatic injuries. *Dent Traumatol* 23(2):95-104, 2007.
32. Kamburoglu K, Ilker Cebeci AR, Grondahl HG, Effectiveness of limited cone beam computed tomography in the detection of horizontal root fracture. *Dent Traumatol* 25(3):256-61, 2009.
33. Bernardes RA, de Moraes IG, et al, Use of cone beam volumetric tomography in the diagnosis of root fractures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 108(2):270-7, 2009.

TO REQUEST A PRINTED COPY OF THIS ARTICLE, PLEASE CONTACT Sotirios Tetradis, DDS, PhD, University of California, Los Angeles, School of Dentistry, 53-068 CHS, 10833 Le Conte Ave., Los Angeles, Calif., 90095.