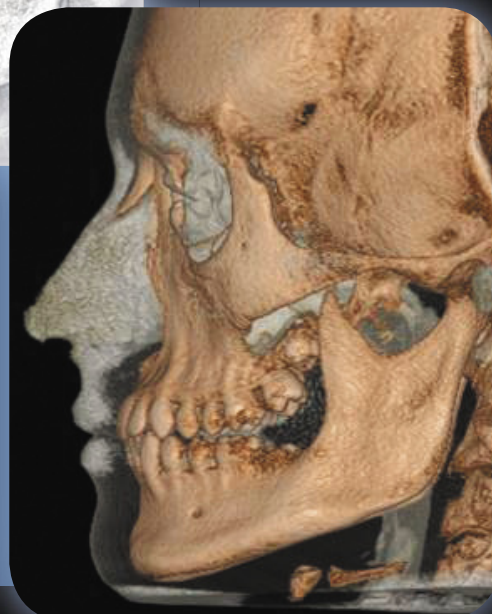


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# A Clinician's Guide to Understanding Cone Beam Volumetric Imaging (CBVI)

A Peer-Reviewed Publication

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## Educational Objectives

1. Understand the differences between Cone Beam Volumetric Imaging (CBVI) and medical CT
2. Understand the principles of CBVI
3. Be knowledgeable about the currently available machines
4. Understand the current applications of CBVI and the legal liabilities associated with CBVI data volumes

## Abstract

Cone Beam Volumetric Imaging has many advantages over simple panoramic film and digital images, including enabling accurate visualization of head and neck structures and reducing X-ray doses. It has been rapidly adopted and is becoming the “standard of care” for several applications and preferred for others.

## Introduction

Since its introduction to North American dentists in 2001, Cone Beam Volumetric Imaging (CBVI), sometimes called Cone Beam Computed Tomography (CBCT) or Cone Beam Volumetric Tomography (CBVT), has rapidly been adopted by dentists, dental specialists and dental radiology lab owners. Adoption of CBVI appears to be much faster than that of intraoral and/or panoramic digital imaging. We believe that this is due in part to CBVI’s incredibly accurate depiction of specific implant sites, and on the orthodontic front because



Figure 1a. Medical CAT scan slice at the level of the condyles.

the cone beam data from the patient is much more accurate and truly a 1:1 display of the dentition and related structures. We also believe that adoption of CBVI by oral and maxillo-facial surgeons for the identification and display of the inferior alveolar nerve in 2D and 3D color will grow rapidly as this imaging modality and its power become better understood. An accurate color image using CBVI enables the surgeon to know the precise nerve location in relation to an impacted third molar, whereas a simple layered panoramic film or digital image does not.

We believe strongly that CBVI will become the “standard of care” for clinical decisions for many procedures in dentistry, including extraction cases, orthodontic assessment, pre-surgical implant site assessment, surgical guide construction and temporomandibular joint evaluation. CBVI is becoming the preferred imaging examination for other applications also. Prepare to be amazed at the images you will see supporting the dental applications of this incredible technology.

## Image Acquisition

Image acquisition of a patient’s data volume using CBVI is much different than when a conventional medical Computed Axial Tomography (CAT) scan is used. A CAT scan requires that the scanner rotate around the head hundreds of times per second, directing a “fan-shaped” beam at an array of multiple detectors consisting of either a gas or scintillator (phosphor coating) material — most commonly cesium iodide (CeI). The patient is moved a known distance in the scanner, usually about 1 cm, 0.5 cm or, in some high-resolution cases, as little as 1 mm. In CAT scans this is termed the “slice thickness.” For thinner slices, the operator must select a “cut” between the initial slice to narrow the desired slice to 0.5 mm. In contrast, CBVI machines perform the initial image acquisition at a 0.15 mm slice thickness, on average.

Although CAT scanning is precise, it necessitates a significant X-ray dose to the patient. A typical CAT scan for a maxillary implant site assessment can be as much as 2,100  $\mu$ SV, the dose equivalent to about 375 panoramic film or

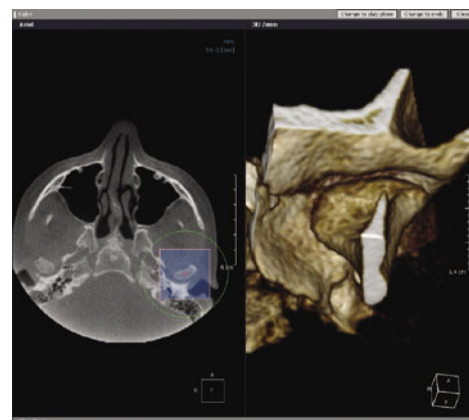
Figure 1b. CBVI 2D grayscale slice at the same level.



Figure 1c. 3D color rendering at a slice thickness of 70 mm.



Figure 1d. A simple “cube” tool gives a 3D color image of the left condyle.



digital images.<sup>1</sup> In contrast, the CBVI machines operate at much lower doses, ranging from about 40 to 500  $\mu$ Sv or as little as four to six panoramic equivalents.<sup>1</sup>

CBVI and the Hounsfield Unit

In 1972, Sir Godfrey Hounsfield invented a quantitative scale, a measure of the radiodensity of the body’s tissues that is still used to evaluate CAT scans today. Pixel data is displayed using this scale in terms of relative density. CBCT/CBVI data is treated a little differently.

“The pixel value is displayed according to the mean attenuation of the tissue that it corresponds to on a scale from –1024 to +3071 on the Hounsfield scale. Water has an attenuation of 0 Hounsfield units (HU), while air is –1000 HU, bone is typically +400 HU or greater, and metallic implants are usually +1000 HU.”<sup>5</sup>

CBVI, unlike CAT scanning, uses a “cone-shaped” beam aimed at a detector (an image intensifier (II), coupled to a CCD array or a flat-panel solid-state detector) that rotates around the patient either totally or partially. Image intensification is older technology. There are distortion patterns that must be “processed out” of the image for display, and the cesium iodide (CsI) coating or in put phosphor will degrade slowly over time, making quality assurance an issue. Units employing II technology will require scintillator (in put phosphor) replacement over time.<sup>2</sup> Flat-panel detectors are the newest image receptors for solid-state large-area arrays.<sup>3</sup> These panels are currently expensive but have some advantages over the older II systems (Table 1).

Table 1. Advantages of flat-panel detectors over II systems.

- No image distortion
- Smaller size of detector
- Fewer components in imaging chain to add noise
- Longer life span
- Better dynamic range

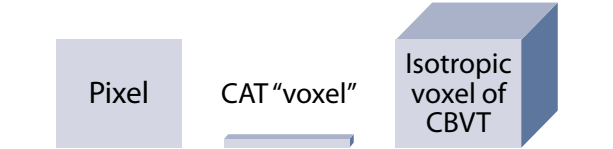
Reconstruction images of the data acquired by CT are displayed in true Hounsfield units (HU), arbitrarily assigning gray shades from –1000 to +1000. This allows the data to display even the gray and white matter of the brain and to separate tissues of similar density by employing sophisticated computer algorithms. Though CBVI machines also display gray scale units, they are not “true” HU. The values assigned to the voxels (volume elements) are relative HU and cannot be used as precisely to estimate bone density. In fact, there is no good data to relate HU to the quality of bone for a desired implant site, although clinicians place great faith in the HU in an attempt to determine whether or not their implant fixture will be placed in “good bone.” Figure 1a shows a typical medical CAT scan slice at the level of the TMJ condyles; due to patient asymmetry, only the right condylar head is seen. Figure 1b shows a CBVI 2D grayscale slice at the same level. Figure 1c shows the 3D color rendering at a slice thickness

of 70 mm displaying more “anatomic” detail. Figure 1d shows a simple “cube” tool within the third-party software (OnDemand3D, CyberMed International). This gives a 3D color image of the left condyle simply and quickly.

Pixel vs. Voxel Information

A pixel (“picture element”) is a small rectangle, anywhere from 20 to 60 microns. The unit area is the same whether an intraoral sensor, a TFT screen or the II/solid-state combination device is used. CCDs and CMOS arrays for intraoral sensors are megapixel arrays; that is, they have 1 million pixels or more. In flat-panel detectors, for example the Planmeca ProMax 3D, there may be as many as 120 million pixels. However, the “pixel” in a CBVI machine is really a “voxel,” or volume element, sometimes described as an “isotropic pixel.” This unit area is a volume or cube with the same length on each side. In conventional medical CT the pixel is “non-isotropic”; it has two equal sides but the third, or “z”-plane, has a selectable width anywhere from 1.0 mm to 1.0 cm or more. The slice thickness of CBVI units is as little as 0.12 mm. An isotropic voxel has the same length, or dimension, on each side (Figure 2). The dimension of each side of the volume element for the CBVI would be only about 0.15 mm, or seven times thinner than the medical voxel on each side.

Figure 2. Pixel, medical CAT scan voxel, CBVI isotropic voxel.



Cross-sectional images of a proposed implant site with these differing slice widths demonstrate the results. Medical CT images of a proposed implant site show low image resolution, and the clinician must use a ruler to “count” the millimeters of height and width (Figures 3a, b). In contrast,

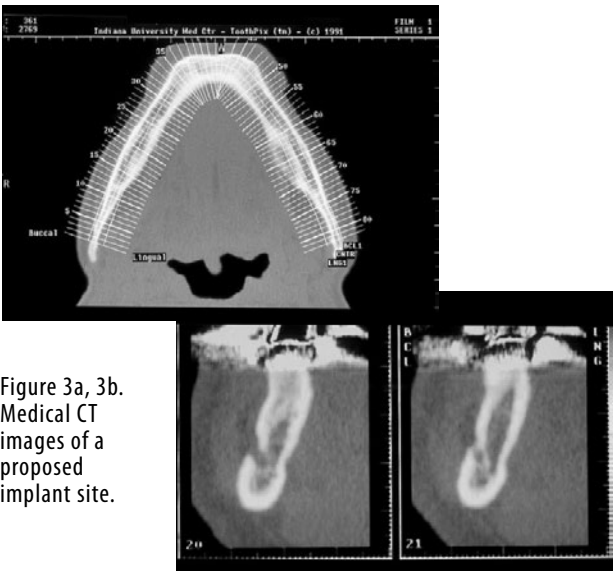


Figure 3a, 3b. Medical CT images of a proposed implant site.



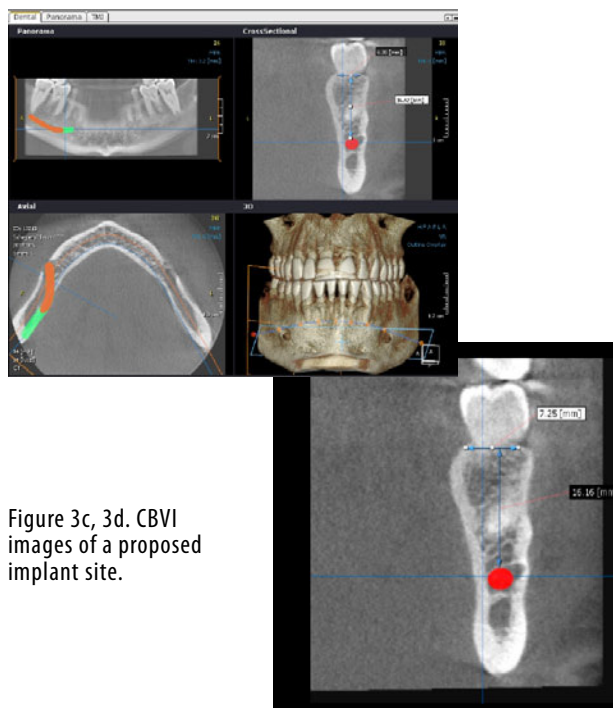


Figure 3c, 3d. CBVI images of a proposed implant site.

Table 2. Applications for which CBVI is preferred.

- Impactions (Figure 5)
- Inferior alveolar nerve location (Figure 5, 6)
- Airway studies for sleep apnea (Figure 7)
- Endodontic evaluation
- Space analysis (because of the 1:1 image data of CBVI)
- Paranasal sinus evaluation; maxillary sinus location (Figure 8)
- Odontogenic lesion visualization
- TMJ structure visualization (Figure 9)
- Trauma evaluation (Figure 10)
- TADs (temporary anchorage devices)
- 3D virtual models
- Other CAD/CAM devices
- Bone structure (dehiscence, fenestration, periodontal defects)

the CBVI images show significant improvement in image resolution (Figures 3c, d). The clinician simply uses a rapid measurement tool to precisely label both the height and width of the site, accurate to within 0.10 mm and the inferior alveolar nerve is marked automatically in red for clear visualization.

### Absorbed X-ray Dose

CBVI doses range from 40 to 500  $\mu\text{Sv}$  depending upon the machine and volume size.<sup>3</sup> Image acquisition using CBVI is very different compared to traditional CT scans because the kV and mA are much lower than with medical units. Table 2 shows the various exposure factors and image acquisition and data reconstruction times for the CBVI machines currently sold in North America.

### Image Data

Although the size of patient data volume is dependent upon the body part of interest in medical CT, the number of images per study (slices) ranges from 400 to 5,000.<sup>4</sup> The actual file

size in megabytes for this data volume also varies. With CBVI the patient's image data can range from 65MB to 250MB, also depending on detector size and the region-of-interest imaged. We look at as many as 512 slices or pictures in three orthogonal planes, or 1,500 slices, to detect occult pathology and report findings, both dental and non-dental! The data set is large and the time required to carefully examine and report is significant. Most dentists and dental specialists will not have the time to examine each volume data set.

### Hard Tissues vs. Soft Tissues

Except for the skin surface, CBVI images are not very good for soft tissue display of tissues with similar densities. If the data could be displayed like true medical CT, then the dentist could not interpret this data with sufficient expertise. As it is, the amount of information “read” by oral and maxillo-facial radiologists requires an organized, systematic, diligent examination process to properly evaluate the data for occult findings. Our service “reads” the following for findings on every single case referred: paranasal sinuses, airway, nasal cavity, temporomandibular joint structures, osseous structures, dental structures, and other findings.

“Other findings” include pharyngeal and nasopharyngeal masses; carotid calcifications, both atherosclerotic and Mönckeberg's; and cranial calcifications. The findings are

Figure 4a. Conventional medical CT slice at the level of the superior surface of the condylar heads. The tips of the coronoid processes are just visible (arrows).



Figure 4b. 3D color reconstruction of the skull slightly superior to the slice level seen in Figure 4a.





Figure 5a. Cuspid impaction, palate.

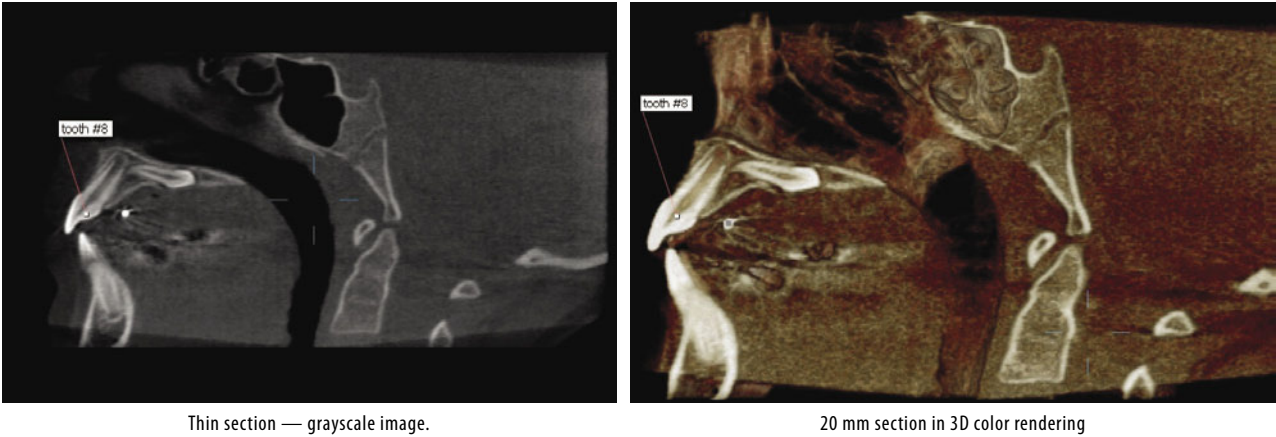


Figure 5b. Molar impactions and inferior alveolar nerve location.

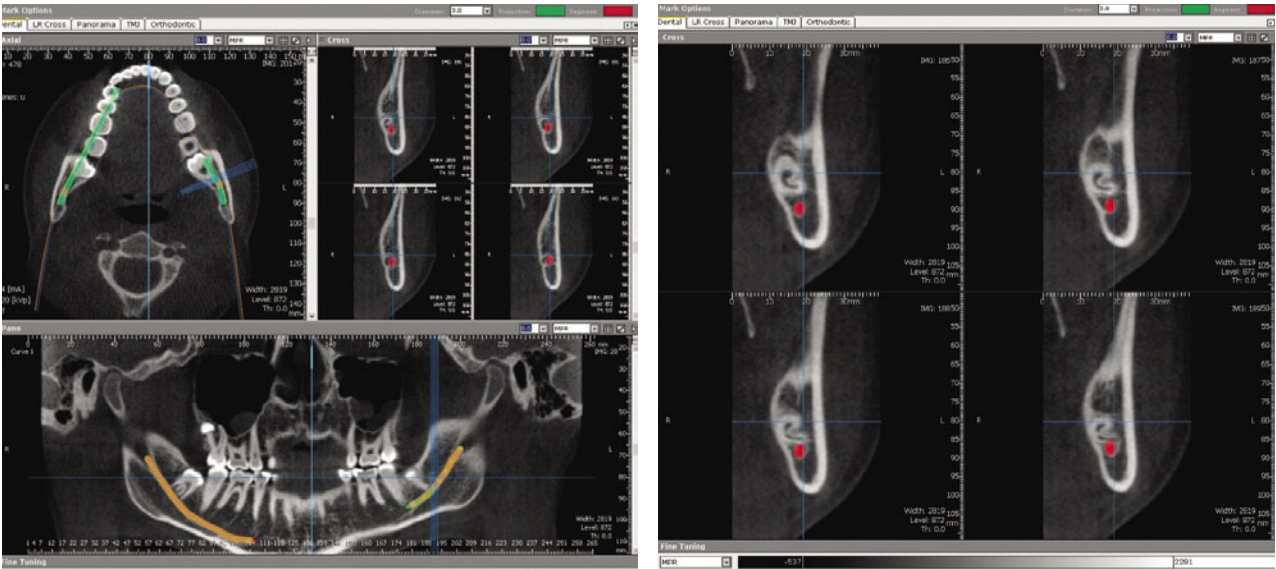
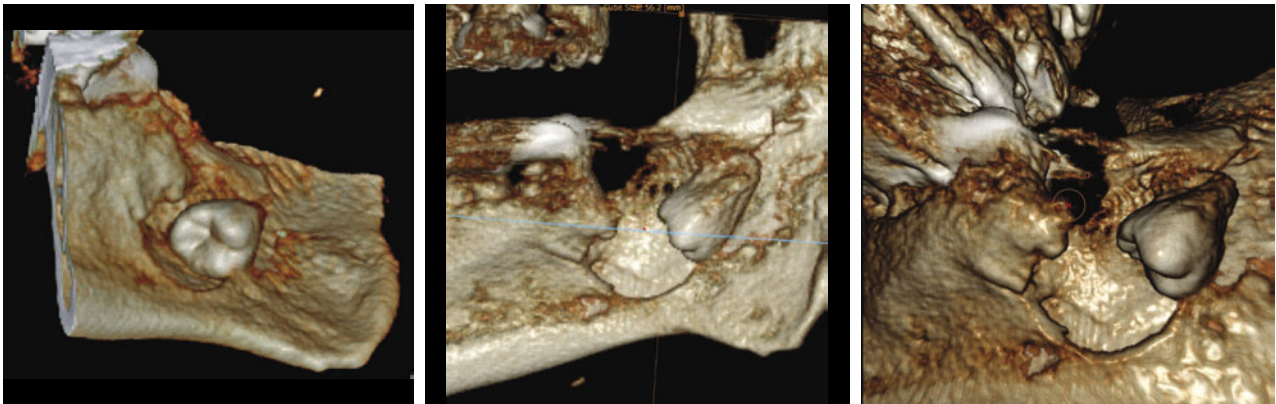


Figure 6. Inferior alveolar nerve location. OKC in “cube modes” and endoscopy. All done in third party software (CyberMed International).

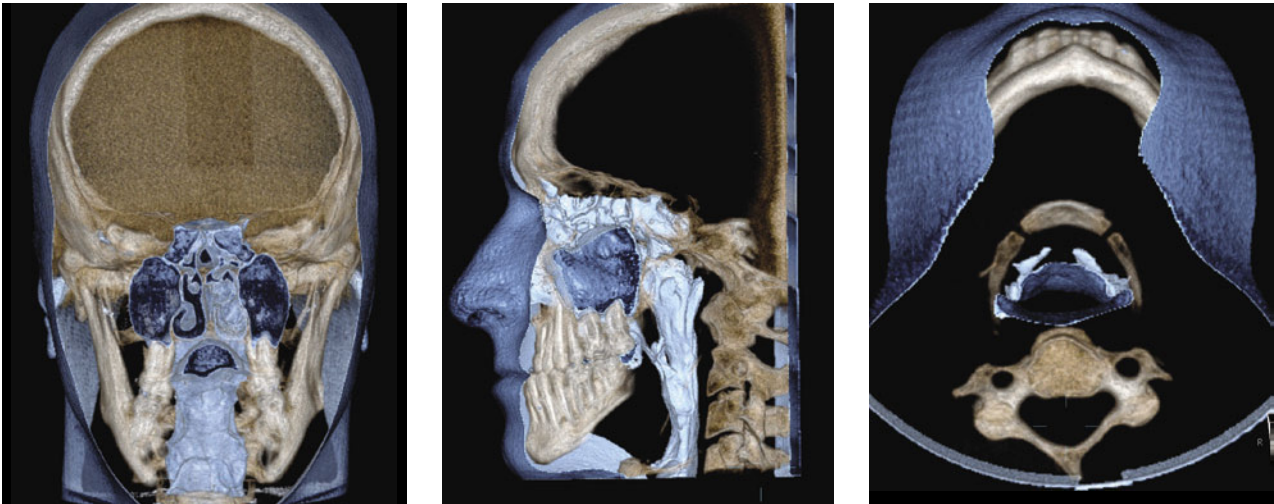
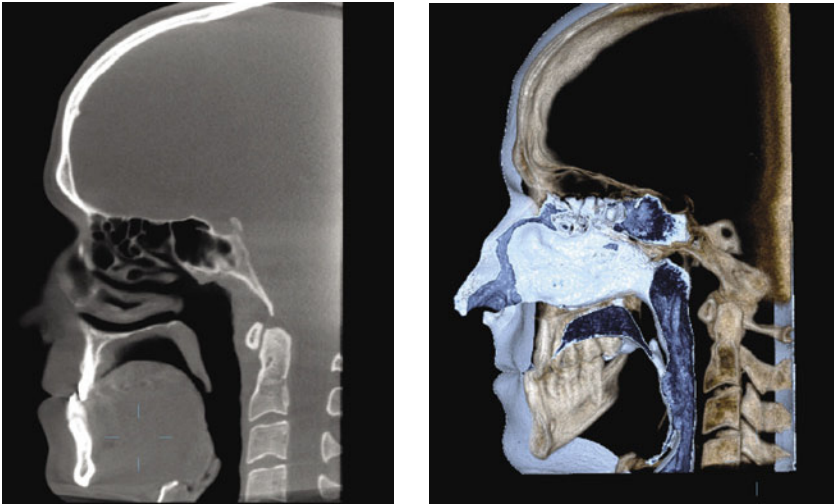


summarized, recommendations made where appropriate and images from the data set embedded in the report for the referring clinician. Figure 4 compares CBVI images and medical CT images at the same slice level. Note the three-dimensional visualization of the coronoid process (arrow). The condylar heads lie just beneath the middle cranial fossa. The floor of

the sphenoid sinus (S) and the ethmoid air cells (EAC) are seen also.

It should be noted that many of the images seen in the center section of this article, for both large and small volume machines, have been performed using “third party” software called “OnDemand 3D” (CyberMed International, Seoul,

Figure 7. Airway studies.



Large volume

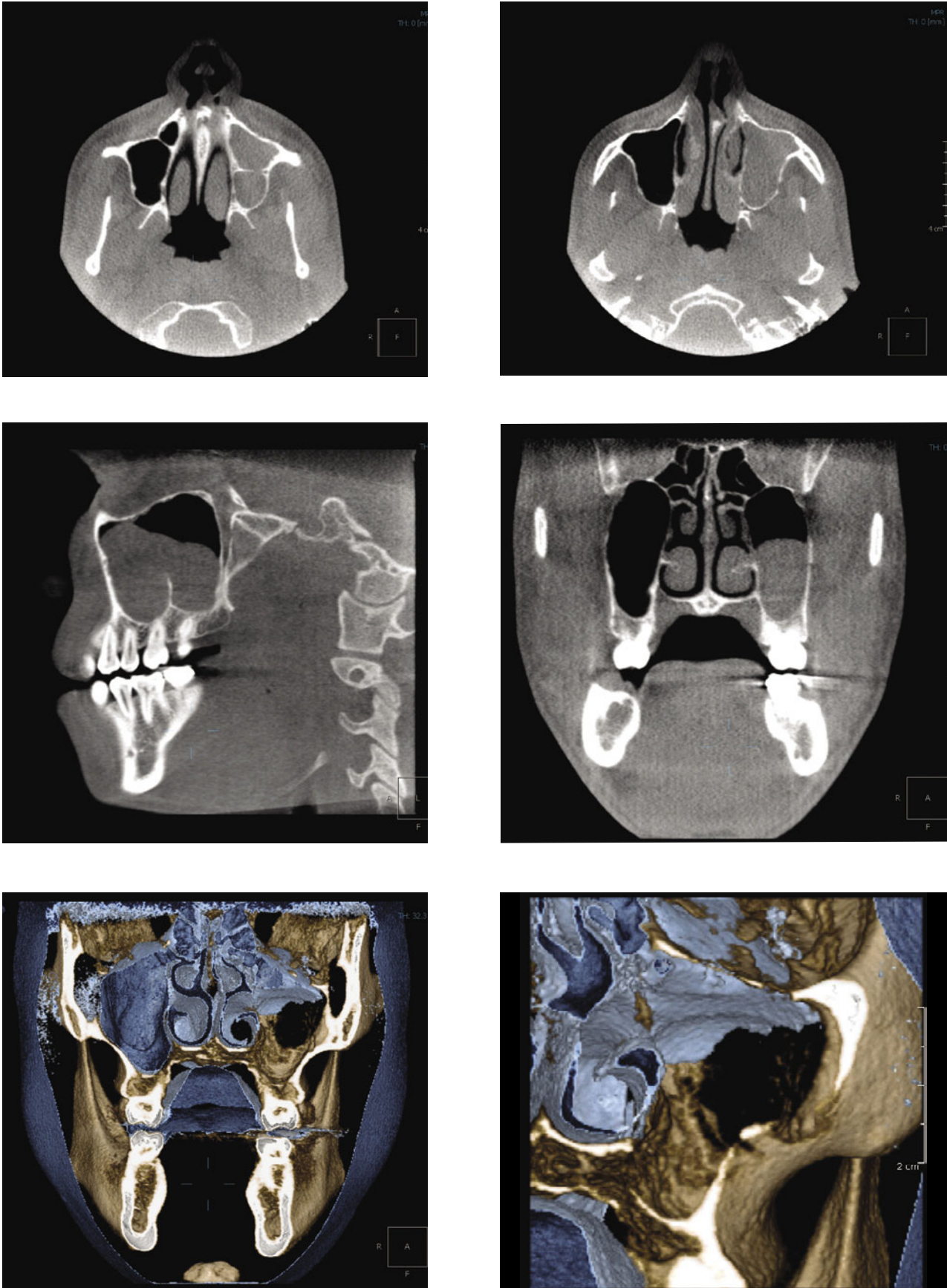
Airways

Small volume





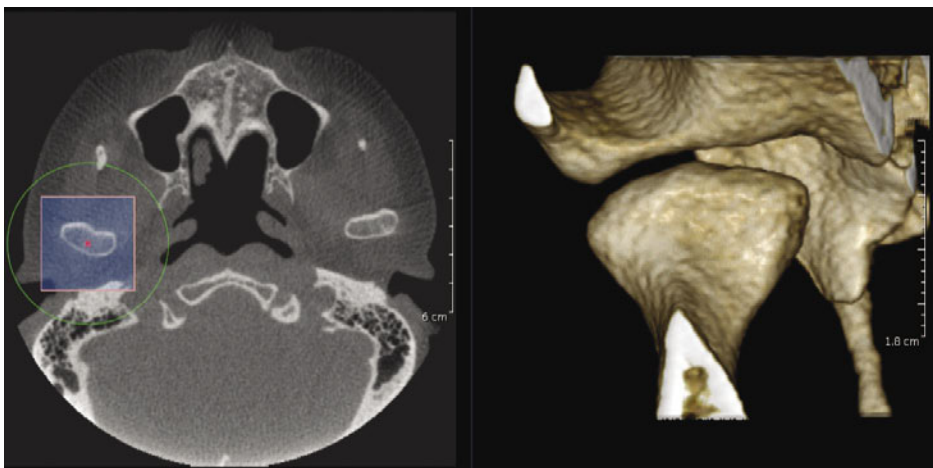
Figure 8. Mucous retention cyst in sinus.



The right sinus in blue is patent. The left shows a void in the processed blue area representing the lesional tissue of the mucous retention cyst



Figure 9a, b, c. Normal condyle in large volume machine.



Axial slice at mid condyle and 3D color image of condylar head done in OnDemand3D software



Coronal slice of case above but in OnDemand3D software



i-CAT “panoramic” created in i-CAT Vision software

Korea). This is the software we use in our “reading service” and versions of this product are currently only available with the Hitachi, Iluma and Planmeca machines. Hitachi and Iluma use a version called “Accurex”, a single client platform. Planmeca has a version trademarked “N-Liten”, specifically designed for their ProMax3D CBVT machine. The software is also available directly from CyberMed. All large volume images seen are from Imaging Sciences i-CAT machines using exported DICOM data volumes. However, the 3D color large volume images displayed cannot be reconstructed using i-CAT’s current proprietary software sold with their machine.

### Applications of CBVI

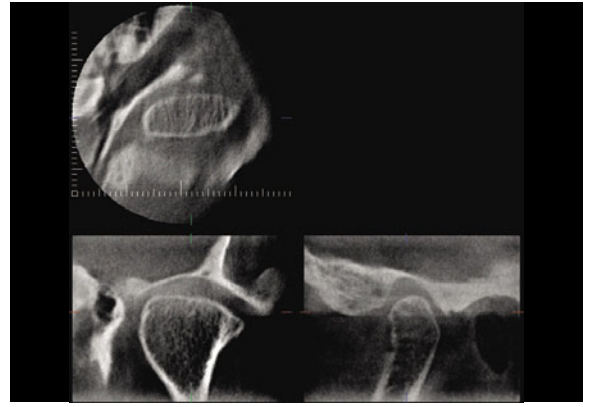
The list of current dental applications is long. In addition to the primary applications cited above for which we believe CBVI will become the “standard of care”, various authors have identified other applications for which CBVI is preferred (Table 2).

### Limitations of Cone Beam Imaging

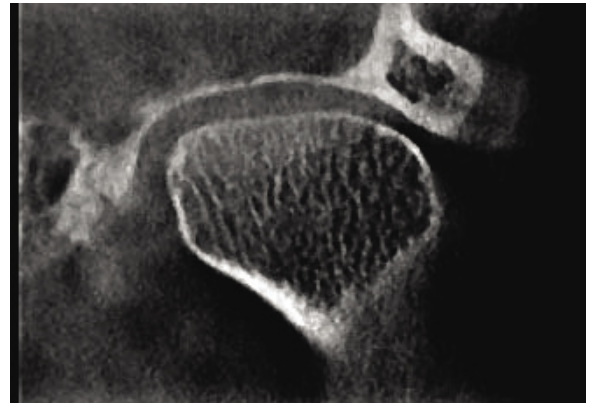
#### Reduced Capability to Display Soft Tissue

Some might argue that the reduced capability to display soft tissue with CBVI is not a disadvantage because of the enor-

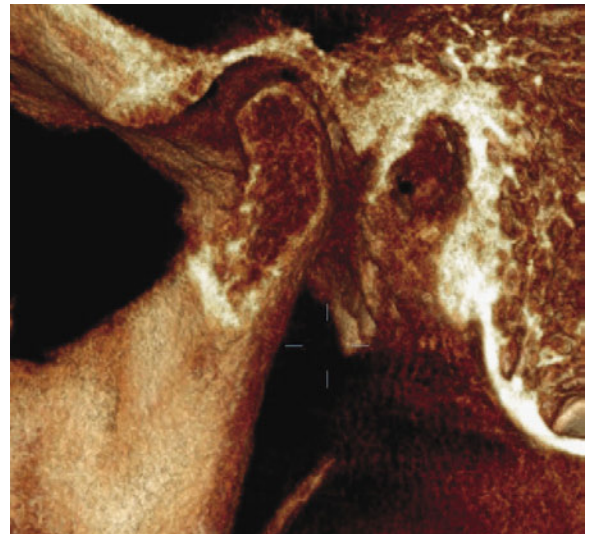
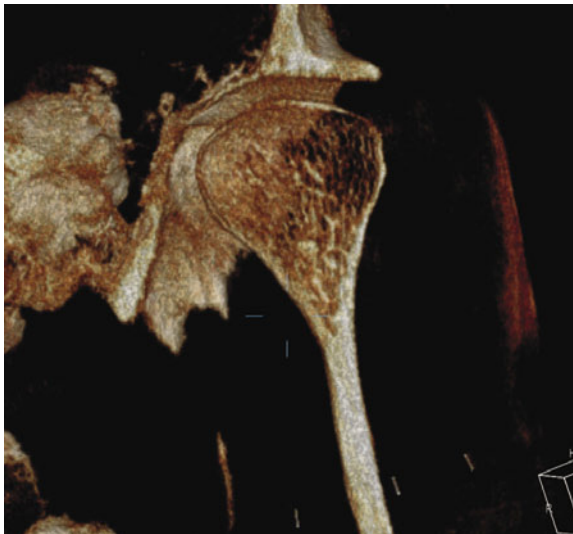
Figure 9d.



J. Morita, small volume TMJ views



J. Morita, left and right TMJ condylar views



Planmeca ProMax 3D CBVT color TMJ views in N-Liten software.

Left – at 10 mm slice thickness. Right – at 22.5 mm thickness to see condylar interior and condyle/fossa relationship

mous number of anatomic structures that a radiologist must master in order to expertly interpret the structures contained within the cranial vault. There are enough important bony and soft-tissue anatomic structures for dentists or dental specialists to contend with in the head and neck. In fact, most of the CBVI volumes we read are at the request of dentists and specialists who do not feel comfortable reviewing the skull contents and

wish to minimize or eliminate their liability by recruiting the expertise of an oral and maxillofacial radiologist. While gray and white matter is not visible, soft tissues such as muscles and glands, and mucosal change in the paranasal sinuses, are visualized quite well. Odontogenic lesions encroaching on the nasal cavity and paranasal sinuses can readily be more prominently visualized than with traditional plain film or digital images.



Figure 10. Mandibular fracture with condylar displacement

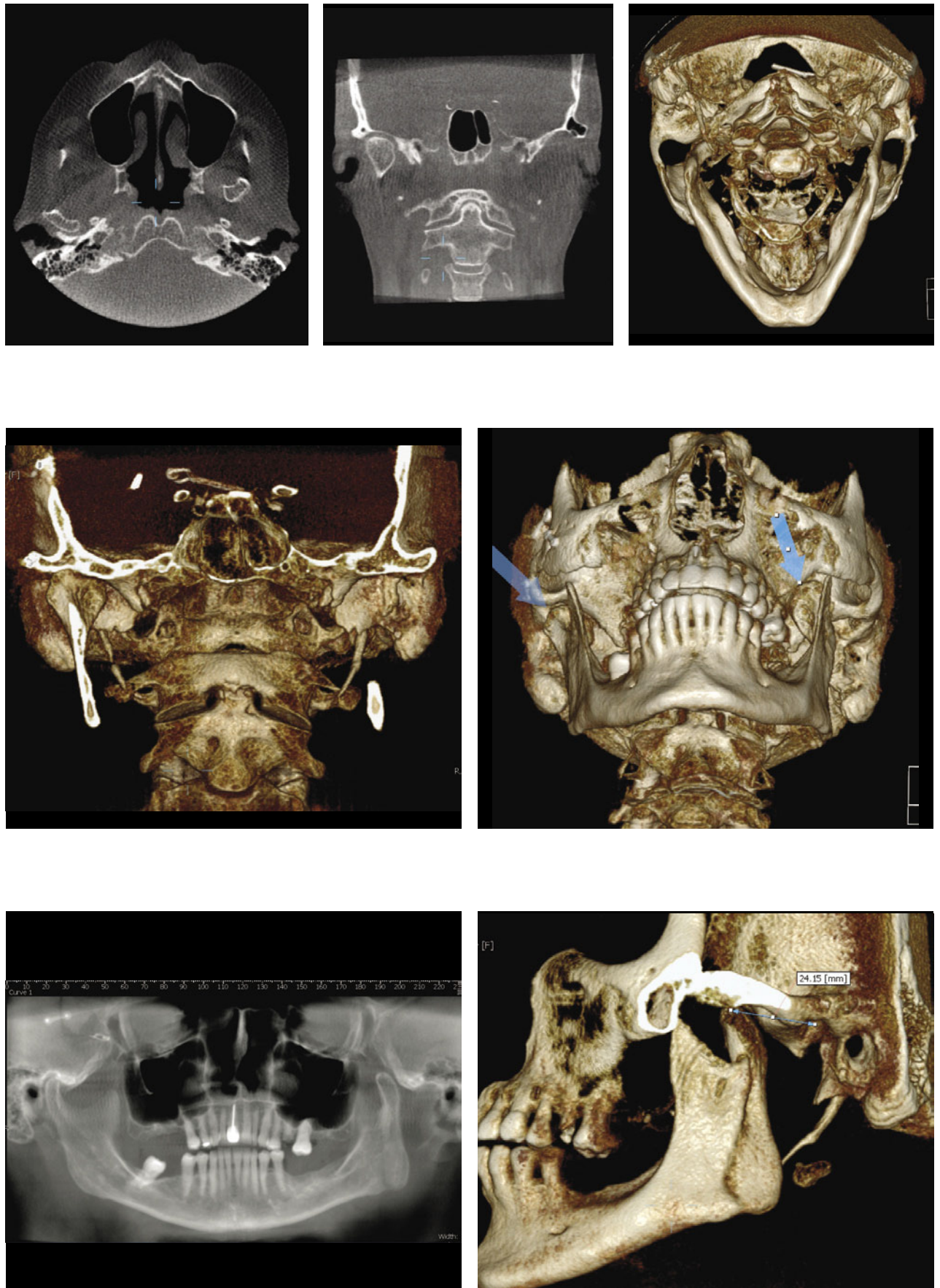


Figure 11. 3D color “surface rendered” mandible with calcified, elongated stylohyoid ligament on patient’s left side.

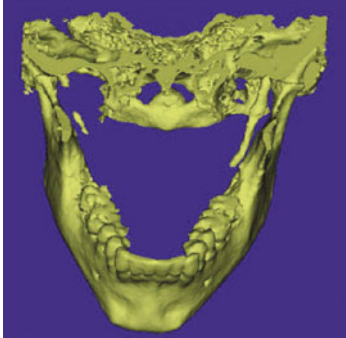


Figure 12. A typical 3D color rendering showing a more “anatomic” image of the styloid process and related structures.

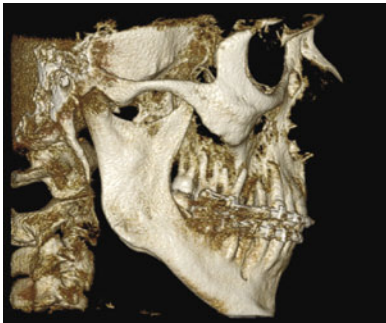


Table 3.

| Objects causing “scatter”                                                                                                                                                                                                                                                                                                         | Objects not causing “scatter”                                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Amalgam restorations</li> <li>• Braces</li> <li>• Prosthetic crowns</li> <li>• Endodontic silver points</li> <li>• Metallic “ball” markers</li> <li>• Lead foil used for implant marking</li> <li>• Barium sulphate (formerly used in tomography for implant site assessment)</li> </ul> | <ul style="list-style-type: none"> <li>• Most implant fixtures</li> <li>• Gutta percha used in root canal therapy</li> <li>• Gutta percha used as implant marker material</li> </ul> |

Not all software is capable of 3D color display in great anatomic detail. Some simply use “surface rendering”, assigning a single color to make the image striking (Figure 11). Others, such as CyberMed International’s OnDemand3D, offer a higher-level software treatment by assigning color, transparency and opacity, which are customizable to make a more life-like 3D color rendering<sup>5</sup> (Figure 12).

### Machine Considerations and Limitations

There are a number of machine considerations and limitations, including artifacts and calibration.

### Artifacts

#### Scatter Radiation and Noise in CBVI

CBVI suffers artifacts similar to conventional medical CAT scans (Table 3). The amount of scatter from cone beam ma-

Figure 13a.

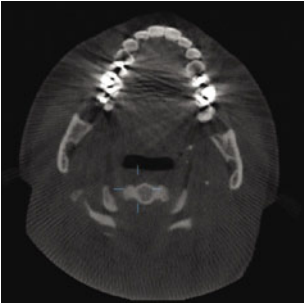


Figure 13b.



Figure 13c.

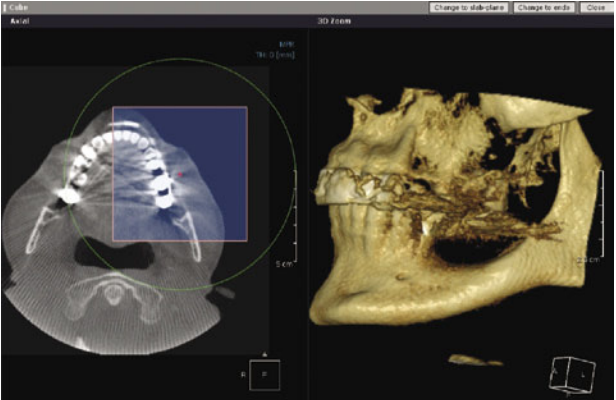
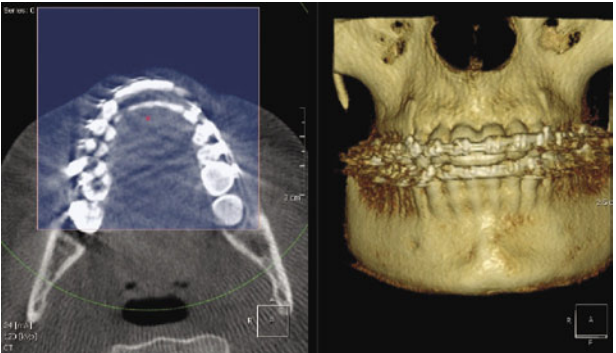


Figure 13d.



chines is much higher than the scatter from the “fan-shaped” beam used in medical CT imaging.<sup>6,7</sup> Figure 13 contains the images of an orthodontic patient. These show scatter, followed by less scatter, following use of a software algorithm to “clean up” the scatter. Most companies use an “antiscatter” or “scatter-correction” algorithm. While CBVI reduces the absorbed X-ray dose, the higher levels of scattered radiation require pre-display image processing algorithms, such as the Feldkamp algorithm,<sup>8</sup> to optimize image quality. Many newer scatter-reduction algorithms are under development for both small- and large-volume machines.<sup>9</sup>

#### “Cupping Artifact”

X-rays from CBVI passing through the mid-portion of a cylindrical object such as an implant are “hardened” more than those passing through the edges of the object, because they pass through more material in the mid-portion. As the center



part of the beam is hardened, the rate of X-ray attenuation decreases and the beam reaching the detector is thus more intense. As a result, the attenuation profile differs from the ideal profile that would be obtained without beam hardening, and the profile of the CT numbers across the implant will display a characteristic cupped shape.

### “Streaking”

In CBVI cross-sections, primarily the axial slices, streaks can appear between two dense objects in an image. Since the portion of the beam that passes through one of the objects at certain X-ray tube positions will be hardened less than when it passes through both objects at other tube positions, streak artifacts are generated. This type of artifact occurs primarily in bony regions and where metallic restorations are located.

### Calibration Requirements

Some CBVI machines require daily or even twice-daily calibration. Manuals for machines such as the Imaging Sciences i-CAT suggest a morning and afternoon calibration. This could reduce the productivity of a busy imaging laboratory. More importantly, if calibration is not performed as part of a quality assurance program, scans could have to be repeated due to image artifacts. Machines such as the Planmeca ProMax3D and the Morita Accuitomo do not require calibration.

### Image Intensification vs. Solid-State

Flat-panel detectors, largely amorphous silicon (a-Si:H) panels, have a higher “collection efficiency” for incident X-rays or photoelectrons than indirect designs such as IIs.

Indirect capture devices have an estimated 50% efficiency, whereas direct detectors such as flat-panel detectors claim almost 98% efficiency for the charge collected in the photoconductor layer.<sup>10</sup> This efficiency may be one of the reasons that image quality is improved in direct systems. In addition, as stated previously, the input phosphors in II systems degrade over time, ultimately resulting in reduced image quality and the need to replace the II itself.

### Machine Size

For anyone planning to purchase a CBVI machine, its size or “ergonomic footprint” may be a significant consideration. Some machines, such as the Hitachi CBMercuray, have more robust imaging capability, but with that capability comes a large unit size. The CBMercuray can perform “real-time” imaging, such as of swallowing or movement of the condyle, but the machine weighs one ton. It cannot be placed in offices on upper stories where the load tolerances of the floor (office ceiling below) are inadequate. With other machines, such as the Planmeca ProMax3D, CBVI is simply accomplished by a detector “swap,” making it the most ergonomic device available. In addition, this machine is the only cone beam device that is upgradeable from an existing panoramic platform. Between these two “extremes” are many other CBVI machines. The machine parameters for various CBVI machines are shown in Table 4.

### Machine Parameters: Volume Size

Many clinicians think they need a “large-volume” CBVI machine. In fact, most do not. You must consider the following questions when making your selection:

1. How much data (how many images) do you need?

Table 4 – Machine Parameters

| Scanner name | Manufacturer     | Detector type | Detector size (cm.) maximum | Voxel size mm <sup>3</sup> | Scan Time (s) | Exp. Time (s)* | Reconstruction time (minutes) | kV       | mA     | Focal spot | Weight lbs. |
|--------------|------------------|---------------|-----------------------------|----------------------------|---------------|----------------|-------------------------------|----------|--------|------------|-------------|
| Accuitomo    | J. Morita        | TFT           | 6 × 6                       | 0.125                      | 18            | 18             | 5.0                           | 60 – 80  | 1 – 10 | 0.5        | 882         |
| CBMercuray   | Hitachi          | II/CCD        | 10.2 – 19                   | 0.2 – 0.38                 | 10            | 10             | 6.0                           | 60 – 120 | 10/15  | Not given  | 2,000       |
| Galileos     | Sirona           | II/CCD        | 15 × 15                     | 0.15 – 0.3                 | 14            | 14*            | 4.5                           | 85       | 5 – 7  | Not given  | 352         |
| Iluma        | Imtec            | TFT           | 19 × 24                     | 0.09 – 0.4                 | 10 – 40       | 10 – 40        | 4.0 at 0.4 voxel              | 120      | 3.8    | 0.3        | 770         |
| I Cat        | Imaging Sciences | TFT?          | 20 × 25                     | 0.12 – 0.4                 | 5 – 25        | 3 – 8*         | < 1                           | 120      | 1-3    | 0.5        | 425         |
| NewTom VG    | AFP              | TFT           | 15 × 16                     | 0.16 – 0.32                | 20            | 5.4            | 3.0                           | 110      | 15     | 0.3        | 550         |
| ProMax3D     | Planmeca         | TFT/CMOS      | 8 × 8                       | 0.16                       | 16 – 18       | 6*             | < 3                           | 84       | 12     | 0.5        | 248         |
| Scanora 3D   | Soredex          | II/CCD        | 7.5 × 14.5                  | 0.15 – 0.35                | 20            | 5              | 3                             | 85       | 8      | 0.4        | 690         |

\*The ProMax3D, Galileos, and it is thought, the i-CAT use a “pulsed exposure”, turning the radiation source off and on at intervals. This lowers the overall radiation absorbed dose substantially.

2. How large an area do you wish to evaluate?
3. Do you need simple 2D grayscale information for your decision?
4. Does the diagnostic task really require CBVI?
5. Does every patient require this type of imaging?
6. Are you comfortable “diagnosing” all of the data?
7. What is your risk of missing an important occult finding?
8. What is the impact on your office workflow?

We will offer a brief discussion of the impact of these questions on your decision to purchase and/or prescribe CBVI.

Not all diagnostic tasks require a cone beam image data set. Simple evaluation of the TMJ surfaces prior to adult orthodontic treatment can probably be addressed by a well-positioned, well-exposed panoramic radiograph. Similarly, determining if third molars are present probably does not require use of CBVI. Not all orthodontists or oral surgeons want to wait 6–10 minutes for image acquisition and image reconstruction just to make an initial assessment. Nor do they have the time to “scroll” through hundreds of slice data to find a panoramic image on which to view the condyles or third molars.

By the same token, a clinician placing only a few implant fixtures per month does not want to assume the cost of the machine. In an office that currently uses images for caries detection and periodontal evaluation, the workflow would be seriously slowed if the dentist had only a cone beam machine for all his/her radiographic needs. It would not make sense or be productive. CBVI, in our opinion, will not replace intraoral or panoramic radiography. All of these techniques are complementary, not exclusionary. One X-ray device will not handle all imaging needs. It hasn’t happened in medicine. It will not happen in dentistry either.

If you do use CBVI for the appropriate tasks, be prepared to look at an enormous amount of image data. You cannot abrogate your responsibility for any occult pathology or reportable finding by having the patient sign a form saying you are not trained to look at all the head and neck data. You must be prepared to look at all the images to see if there are significant changes or findings, describe these findings and take the appropriate action. This may simply be a referral for treatment or for additional evaluation to another specialist if an area looks unusual. What you cannot afford to do is miss a finding and thus put you and your practice, as well as the laboratory or colleague who may have performed the image acquisition, at significant risk. The reader is re-directed to the questions above to determine his/her “comfort level” with adopting cone beam technology in the office.

## Final Thoughts

There is no doubt that this is the most exciting imaging technology to come to our profession in the past 20 years.

Many clinicians will embrace this technology because of the wide number of applications, better decision-making data and lower radiation dose. However, like any other technology adoption, you must first educate yourself about the technology and determine how it could improve your practice and treatment of your patients. Only then can you attain the comfort level necessary to use the technology skillfully. We hope that this article helps you to achieve this goal.

## References

- 1 Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G, and i-CAT. *Dentomaxillofac Radiol.* 2006;35:219–226.
- 2 Correction statement for dose units. *Dentomaxillofac Radiol.* 2006;35:392.
- 3 de Groot PM. Image intensifier design and specifications, Thales Electron Devices, Moirans, France, 1991.
- 4 Wang J, Blackburn TJ. The AAPM/RSNA physics tutorial for residents: X-ray image intensifiers for fluoroscopy. *RadioGraphics* 2000;20:1471–1477.
- 5 Fishman EK, Ney DR, Heath DG, Corl FM, Horton KM, Johnson PT. Volume rendering versus maximum intensity projection in CT angiography: what works best and why. *RadioGraphics.* 2006;26:905–922.
- 6 Rinkel J, Esteve F, Dinten JM. Evaluation of a physical based approach of scattered radiation correction in cone beam CT for non-destructive testing applications. ECNDT Poster #39, Proceedings of the ECNDT Conference 11(11), Berlin 2006.
- 7 Endo M, Tsunoo T, Nakamori N, Yoshida K. Effect of scattered radiation on image noise in cone beam CT. *Med Physics.* 2001;28:469–474.
- 8 Xiao S, Bresler Y, Munson DC. Fast Feldkamp algorithm for Cone-Beam Computer Tomography. Dept. of Electrical and Computer Engineering and Coordinated Science Library, University of Illinois at Urbana-Champaign, U.S. Army Research Office, contract 38310-PH DAAG55-98-1-0039.
- 9 Yang D, Ning R. FDK Half-scan with heuristic weighting scheme on a flat panel detector-based cone beam CT (FDKHSCW). *Int J Biomedical Imaging.* 2006;2006:1–8.
- 10 Yorkston J. Digital radiographic technology, advances in digital radiography: RSNA categorical course in diagnostic radiology physics 2003;23–36.

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## Questions

1. Cone Beam Volumetric Imaging (CBVI) was first introduced to North American dentists in \_\_\_\_\_.
  - a. 1997
  - b. 1999
  - c. 2001
  - d. 2003
2. A head and neck CAT scan \_\_\_\_\_.
  - a. requires that the scanner rotate around the head hundreds of times per second
  - b. directs a "fan-shaped" beam at an array of multiple detectors
  - c. is the most recent method of imaging available
  - d. a and b
3. CBVI machines currently can perform the initial image acquisition at a slice thickness of as little as \_\_\_\_\_.
  - a. 0.12 mm
  - b. 0.15 mm
  - c. 0.25 mm
  - d. 0.5 mm
4. CBVI absorbed X-ray doses typically range from \_\_\_\_\_.
  - a. 20 – 40  $\mu$ Sv
  - b. 40 – 50  $\mu$ Sv
  - c. 40 – 500  $\mu$ Sv
  - d. 500 – 2,100  $\mu$ Sv
5. The quantitative scale used to evaluate CAT scans was invented by \_\_\_\_\_.
  - a. Sir Hillary Edmund
  - b. Sir Walter Raleigh
  - c. Sir Godfrey Hounsfield
  - d. Sir Godfrey Hounsfield
6. CBVI uses a "cone-shaped" beam \_\_\_\_\_.
  - a. at the detector
  - b. coupled to a CCD array or flat-panel solid-state detector
  - c. that results in no distortion
  - d. a and b
7. The newest image receptors for solid-state large-area arrays are \_\_\_\_\_.
  - a. image intensifier systems
  - b. flat-panel detectors
  - c. cesium cylinders
  - d. a and c
8. CBVI machines display gray scale units that \_\_\_\_\_.
  - a. are true Hounsfield units
  - b. are not true Hounsfield units
  - c. can be used precisely to estimate bone density
  - d. a and c
9. CBVI has a volume element known as a \_\_\_\_\_.
  - a. poxel
  - b. voxel
  - c. isotropic voxel
  - d. paxel
10. CBVI X-ray doses \_\_\_\_\_.
  - a. range from 30 to 300  $\mu$ Sv
  - b. depend upon the machine and volume size
  - c. range from 40 to 500  $\mu$ Sv
  - d. b and c
11. The number of images (slices) per study using medical CT \_\_\_\_\_.
  - a. ranges from 400 to 5,000
  - b. results in the actual file size in megabytes being constant
  - c. is less than with conventional film radiography
  - d. can be reduced with altered voltages
12. Using CBVI, the number of slices in total examined in three orthogonal planes is approximately \_\_\_\_\_.
  - a. the same as using medical CT
  - b. up to 1,500 slices
  - c. less than using medical CT
  - d. none of the above
13. CBVI images \_\_\_\_\_.
  - a. are not very good for soft tissue display of tissues with similar densities
  - b. are good for display of the skin surface
  - c. suffer artifacts similar to those of conventional medical CAT scans
  - d. all of the above
14. Findings read on every single case using CBVI should at a minimum include \_\_\_\_\_.
  - a. paranasal sinuses, nasal cavity and airways
  - b. TMJ structures
  - c. osseous and dental structures
  - d. all of the above
15. "Other" findings read on cases using CBVI may include \_\_\_\_\_.
  - a. carotid calcifications
  - b. cranial calcifications
  - c. pharyngeal masses
  - d. all of the above
16. Some "third party" software allows the radiologist to:
  - a. render 3D color images of pathology
  - b. assign color, opacity and transparency to voxels
  - c. only use "surface rendering" for color
  - d. a and b
17. Applications for which CBVI is preferred in dental settings, in addition to those where it is believed by the authors that it will become "standard of care," include \_\_\_\_\_.
  - a. inferior alveolar nerve location
  - b. trauma evaluation
  - c. orbital evaluation
  - d. a and b
18. All software used with CBVI is capable of 3D color display in great anatomic detail.
  - a. True
  - b. False
19. Scatter radiation \_\_\_\_\_.
  - a. results in artifacts in both medical CAT scans and CBVI
  - b. results in artifacts in only CBVI
  - c. does not result in artifacts
  - d. only occurs with non-metallic substances
20. Scatter radiation \_\_\_\_\_.
  - a. is caused by metallic objects such as amalgam restorations
  - b. is corrected for using software algorithms
  - c. is of no consequence
  - d. a and b
21. "Cupping artifacts" occur \_\_\_\_\_.
  - a. only when a circular object is being imaged
  - b. because X-rays from CBVI passing through the midpoints of cylindrical objects are "hardened" more than those passing through the edges of the object
  - c. only because the cone beam machine is not properly calibrated
  - d. a and b
22. "Streaking" \_\_\_\_\_.
  - a. can appear between two thin objects in an image
  - b. can appear between two dense objects in an image
  - c. occurs primarily in bony regions
  - d. b and c
23. Some cone beam machines must be calibrated twice-daily.
  - a. True
  - b. False
24. If calibration is required and not performed, \_\_\_\_\_.
  - a. patients are at serious risk of the machine collapsing
  - b. scans may have artifacts as a result
  - c. scans may need to be repeated
  - d. all of the above
25. Machines that do not require calibration include the \_\_\_\_\_.
  - a. Planmeca ProMax3D
  - b. Curaray
  - c. Morita Accura
  - e. a and c
26. Flat-panel detectors \_\_\_\_\_.
  - a. have a higher "collection efficiency" than indirect designs do
  - b. claim almost 98% efficiency for the charge collected in the photo-conductor layer
  - c. are the oldest technology available
  - d. a and b
27. Image intensifiers \_\_\_\_\_.
  - a. are older technology than flat-panel detectors
  - b. need to be replaced over time because the input phosphors degrade over time
  - c. a and b
  - d. none of the above
28. If a CBVI machine weighs one ton, \_\_\_\_\_.
  - a. it always has less robust imaging capability than lighter machines do
  - b. the load tolerances of the floor must be considered
  - c. it cannot be used for dental imaging
  - d. a and b
29. In considering CBVI, a factor that should be considered is \_\_\_\_\_.
  - a. how often it would be used
  - b. whether it is better to refer patients out for CBVI
  - c. the impact on office workflow
  - d. all of the above
30. If you use CBVI, \_\_\_\_\_.
  - a. you must be prepared to interpret all the data on the images
  - b. you must be prepared to describe the findings and take appropriate action
  - c. be sure to have the patient sign a form indicating that you cannot interpret all head and neck data
  - d. a and b

# A Clinician's Guide to Understanding Cone Beam Volumetric Imaging (CBVI)

|                               |                      |                  |
|-------------------------------|----------------------|------------------|
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## Educational Objectives

1. Understand the differences between Cone Beam Volumetric Imaging (CBVI) and medical CT
2. Understand the principles of CBVI
3. Be knowledgeable about the currently available machines
4. Understand the current applications of CBVI and the legal liabilities associated with CBVI data volumes

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Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

- |                                                                                               |                      |                      |
|-----------------------------------------------------------------------------------------------|----------------------|----------------------|
| 1. Were the individual course objectives met?                                                 | Objective #1: Yes No | Objective #3: Yes No |
|                                                                                               | Objective #2: Yes No | Objective #4: Yes No |
| 2. To what extent were the course objectives accomplished overall?                            | 5 4 3 2 1 0          |                      |
| 3. Please rate your personal mastery of the course objectives.                                | 5 4 3 2 1 0          |                      |
| 4. How would you rate the objectives and educational methods?                                 | 5 4 3 2 1 0          |                      |
| 5. How do you rate the author's grasp of the topic?                                           | 5 4 3 2 1 0          |                      |
| 6. Please rate the instructor's effectiveness.                                                | 5 4 3 2 1 0          |                      |
| 7. Was the overall administration of the course effective?                                    | 5 4 3 2 1 0          |                      |
| 8. Do you feel that the references were adequate?                                             | Yes No               |                      |
| 9. Would you participate in a similar program on a different topic?                           | Yes No               |                      |
| 10. If any of the continuing education questions were unclear or ambiguous, please list them. |                      |                      |

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| 1. (A) (B) (C) (D)  | 16. (A) (B) (C) (D) |
| 2. (A) (B) (C) (D)  | 17. (A) (B) (C) (D) |
| 3. (A) (B) (C) (D)  | 18. (A) (B) (C) (D) |
| 4. (A) (B) (C) (D)  | 19. (A) (B) (C) (D) |
| 5. (A) (B) (C) (D)  | 20. (A) (B) (C) (D) |
| 6. (A) (B) (C) (D)  | 21. (A) (B) (C) (D) |
| 7. (A) (B) (C) (D)  | 22. (A) (B) (C) (D) |
| 8. (A) (B) (C) (D)  | 23. (A) (B) (C) (D) |
| 9. (A) (B) (C) (D)  | 24. (A) (B) (C) (D) |
| 10. (A) (B) (C) (D) | 25. (A) (B) (C) (D) |
| 11. (A) (B) (C) (D) | 26. (A) (B) (C) (D) |
| 12. (A) (B) (C) (D) | 27. (A) (B) (C) (D) |
| 13. (A) (B) (C) (D) | 28. (A) (B) (C) (D) |
| 14. (A) (B) (C) (D) | 29. (A) (B) (C) (D) |
| 15. (A) (B) (C) (D) | 30. (A) (B) (C) (D) |

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CONE0708DE





# The agony and ecstasy of buying cone beam technology

## Part 1: The Ecstasy

Dale A. Miles<sup>1</sup>

### Abstract

**Background:** Since arriving in North America in 2001, cone beam computed tomography (CBCT) has been rapidly and enthusiastically embraced by the dental profession. With nearly two dozen CBCT systems currently available, dental providers are faced with a number of options when they consider purchasing this new technology. This aim of this article is to present introductory information on cone beam machines, the wide array of applications made possible by the incredible variety of image output choices, and decision points to aid the reader in their decision making process for purchasing CBCT systems. **Methods:** The author reviews a number of CBCT articles published in dental literature and draws upon his personal experience from analysis of over 3,700 CBCT cases. **Results:** CBCT applications, image outputs and decision points for purchase are discussed. 5 cases with various CBCT applications are discussed. **Conclusion:** Use of CBCT technology provides unique and valuable information that is unobtainable in any other format. This information can benefit practitioners in all aspects of dental treatment.

**Key words:** Cone beam computed tomography, digital radiography, radiographic image enhancement

### Introduction

Cone Beam Computed Tomography (CBCT) has been rapidly and enthusiastically embraced by the dental profession in a much more dramatic way than “digital x-ray imaging”. Introduced in 1988, it has taken our profession over 20 years to reach a 40% adoption level with digital x-ray systems. In contrast, since arriving in North America in 2001<sup>1</sup>, cone beam manufacturers have gone from one available system, the NewTom (initially QR Systems, Verona, Italy – acquired by AFP Imaging Corporation, Elmsford, NY), to over 13 currently available systems. This does not count companies making more than one version of their machine. A previous publication by Cattaneo and Melsen,<sup>2</sup> to which the reader is

referred for an excellent CBCT resource, gives a more complete description of machine parameters such as scan size, voxel size, kilovoltage, and milliamperage.

Because of the rapid introduction and adoption of CBCT technology, dentists and dental specialists have been offered so many choices that the decision making process is as complex and difficult as it was for digital x-ray adoption. The primary difference, however, is the huge cost of cone beam machines which can range in price from \$120,000 to \$350,000! Despite this enormous investment, dentists are discovering the advantages of cone beam imaging and taking the plunge.

In the first part of this article, “the Ecstasy”, I present introductory information on cone beam machines, the wide array of applications made possible by the incredible variety of image output choices, and some decision points to help you decide which cone beam device might best suit your practice.

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### The ecstasy of CBCT: applications, image output and decision points for purchase

Many recent articles on CBCT have reported quite a number of applications.<sup>3-8</sup> While these current applications may change somewhat over time, table 1 presents what I feel will be the primary applications that may become the “standard of care” or commonplace for particular dental tasks.<sup>9</sup>

The cases below graphically illustrate the impact of CBCT

**Table 1**

| Clinician                             | Task(s)                                                                                                                                    |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>General Dentist</b>                | Implant site assessment<br>TMJ evaluation<br>Paranasal sinus evaluation<br>Airway analysis (sleep disorders)                               |
| <b>Endodontist</b>                    | Root form, pulp canal assessment<br>Periapical lesion assessment<br>Implant site assessment<br>“Re-treatment”                              |
| <b>Orthodontist</b>                   | Space analysis<br>Impactions<br>Treatment “records”<br>Craniofacial anomaly assessment<br>TMJ evaluation<br>Supernumerary tooth assessment |
| <b>Oral and Maxillofacial Surgeon</b> | Third molar assessment<br>Orthognathic surgery<br>Pre-surgical planning for lesions<br>Paranasal sinus evaluation<br>TMJ evaluation        |
| <b>Pediatric Dentist</b>              | Tooth development                                                                                                                          |
| <b>Periodontist</b>                   | Bone grafting<br>Implant site assessment<br>TMJ evaluation                                                                                 |
| <b>Prosthodontist</b>                 | Implant site assessment                                                                                                                    |

on the assessment of various relatively common patient problems encountered by dentists.

### Cases 1 and 2: Impacted teeth in the mixed dentition

One of the more common problems for dentists, orthodontists, and oral & maxillofacial surgeons is to assess the position of impacted permanent teeth for exposure and repositioning into the correct occlusal position. We have all suffered through and continue to use the “Buccal Object Rule” or “SLOB (Same on Lingual, Opposite on Buccal) Rule” to determine the position of impacted teeth.<sup>11</sup> The cases below, Figures 1a-1e and 2a-2d, show 2 patients with different permanent tooth impactions and the advantage of having CBCT information for the surgeon and orthodontist.

**Case 1:** A fifteen year-old white female with an impacted maxillary right cuspid and developing third molars.

**Case 2:** A fifteen year-old white female with an impacted maxillary right cuspid and developing third molars.



**Figure 1a:** A reconstructed panoramic image, simulating a conventional panoramic, showing the impaction of tooth #6. From this image, the clinician cannot determine if the tooth is impacted facially or palatally.



**Figure 1b:** A reconstructed MIP (Maximum Intensity Profile) image provides improved clarity, but is still inadequate for determining tooth position. Note the complete root formation and the developing third molar follicle positions.



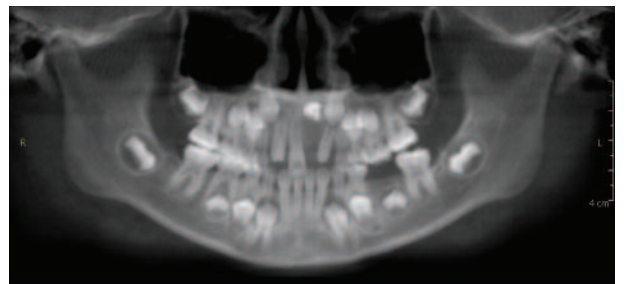
**Figure 1c:** A 3D reconstructed color image reveals that the cuspid crown is palatal to the lateral incisor. Note the complete lack of space clinically for this tooth.



*Figure 1d: (left) Axial image showing the crown position of tooth #6. (right) Sagittal view showing the crown position of tooth #6 and its follicular space palatal to tooth #7.*



*Figure 1e: A 3D reconstructed color image reveals the “true” position of the impacted cuspid. This image and related CBCT images allow for improved surgical planning in comparison to standard digital images.*

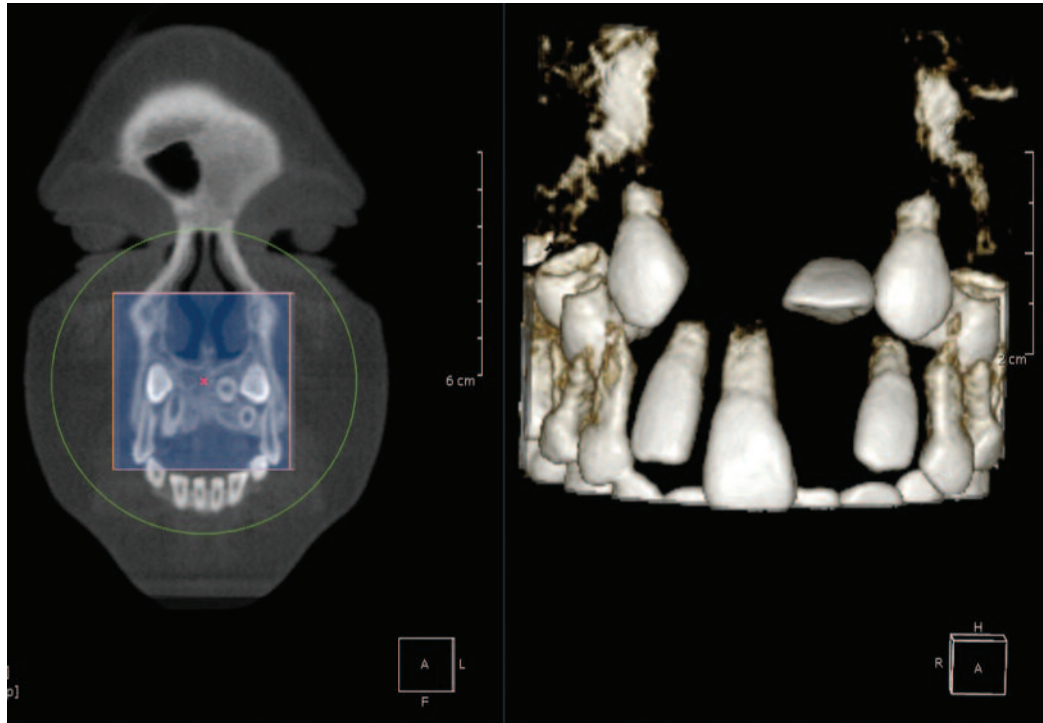


*Figure 2a: A reconstructed panoramic image reveals normal tooth development except for tooth #9. In this image the tooth almost appears deformed or even replaced by an odontogenic malformation such as an odontoma.*

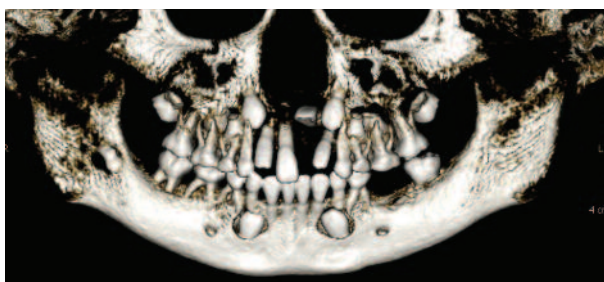


*Figure 2b: A sagittal view of this tooth shows normal development of the crown and root, but a very unique horizontal impaction. This image and related CBCT images allow for improved surgical planning in comparison to standard digital images.*





*Figure 2c: (left) 3D color reconstruction using a “Cube” tool in OnDemand 3D third party software (CyberMed International, Seoul, Korea) shows the sub-mucosal position of developing teeth #6, 9, and 11. (right) The same image made “transparent” to remove the thin bone and allow better visualization of the dentition.*



*Figure 2d: A 3D color panoramic reconstruction shows all tooth relationships and root development.*

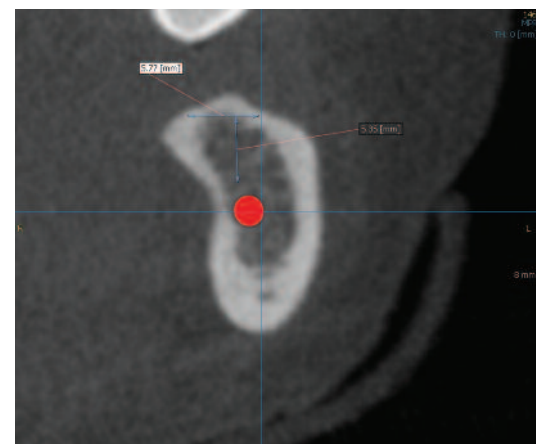
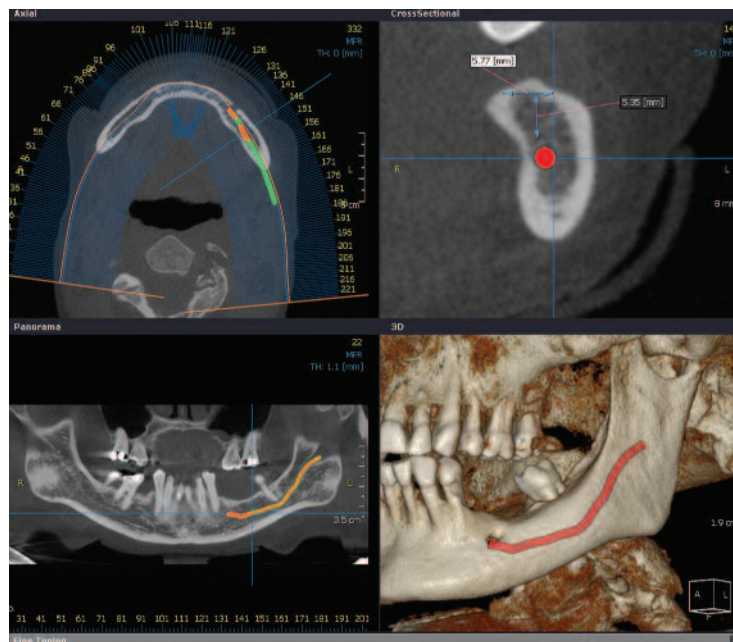
### Case 3: Pre-surgical implant imaging

Perhaps the most widely adopted application for CBCT to date is implant site assessment. Images from any cone beam machine are rendered in a precise 1:1 ratio in reconstruction software provided by the vendor. Dentistry has never had this capability before. All of our previous image applications (periapical, panoramic, and cephalometric) have been magnified and distorted because of the nature of the image capture. The precise 1:1 ratio of CBCT images allows the



*Figure 2e: A 3D color skull reconstruction of the potential problems.*

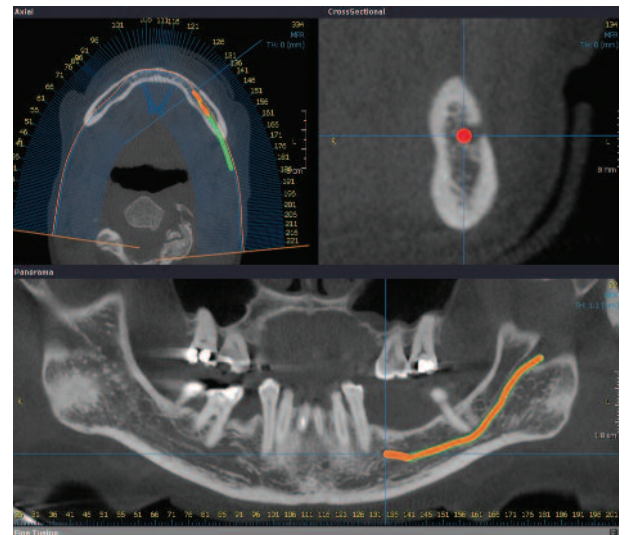
clinician to have very large and accurate implant site images rather than the older “life size” images displayed in medical



**Figure 3a:** (left) Multiple views of a proposed implant site. (above) View captured directly in the software, enlarged for planning and displaying to the patient in practice management software. Since image reconstruction is 1:1, the image may be displayed at any size on the monitor or if printed. The measurements depicted are accurate to within 0.1 mm.



**Figure 3b:** (above) A 3D color reconstruction of the patient rotated to show left mandible. Note the detail of the bony anatomy. (right) This slice pseudopanoramic used to “paint” the inferior alveolar nerve canal, allows reconstruction of the anterior implant site showing the canal painted in red exiting the mental foramen.



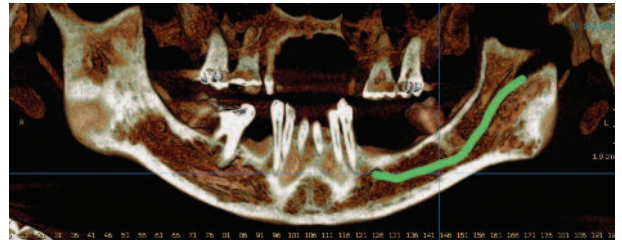
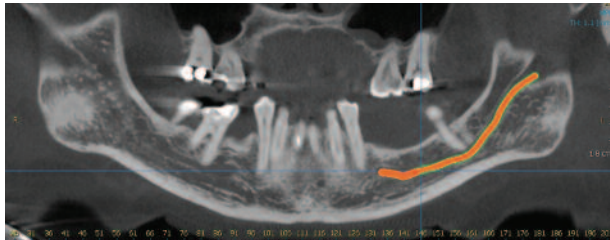
CAT scan software of the past. The width and height of the proposed site are also measured with an accuracy of 0.1mm. Figure 3a illustrates this concept.

Image 3d depicts some of the ways to display implant information available in this third party software (OnDemand 3D, CyberMed International, Seoul, Korea).

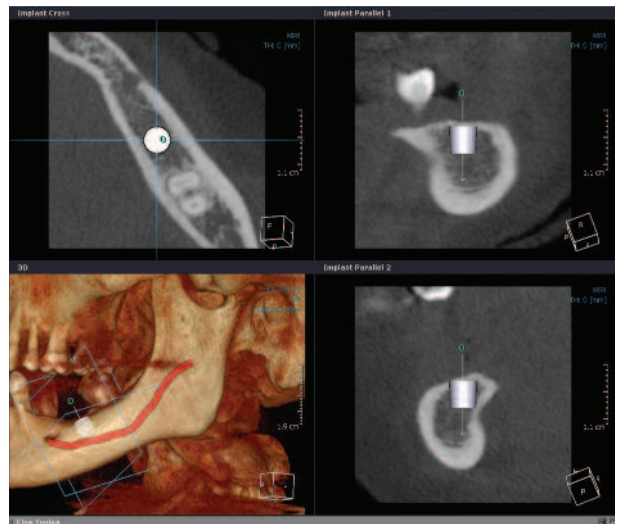
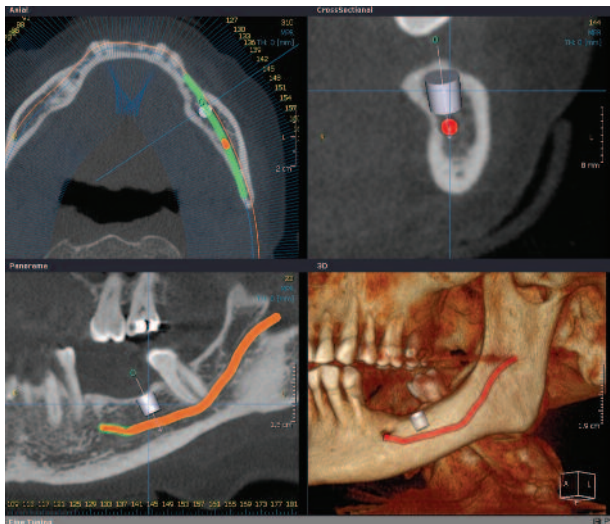
## Cases 4-5: Assessment of the temporomandibular joint complex

Until now, dentists have had to rely on 2D grayscale images and radiographic interpretations of condylar changes to determine the severity of a condylar problem and how it should be managed. To visualize disc displacement





**Figure 3c: (top)** This slice pseudopanoramic reconstructed at 1.0 mm thickness showing location and path of inferior alveolar nerve canal. **(bottom)** color rendition thickened to about 10mm.



**Figure 3d: (left)** Selected “mini-implant” placed by operator into site for visualization. **(right)** A “Verification” tool allows precise adjustments to show an implant can be placed, verified in the axial and sagittal views.

problems, we still have to rely on magnetic resonance imaging or arthroscopy to see the “soft tissues” to the TMJ complex. Bony changes, however, are easily and completely imaged by CBCT. Conditions such as osteoarthritic changes, synovial chondromatosis, and rheumatoid arthritis can be seen in color in three dimensions. Additionally, it is simple to correlate vertebral body changes in the cervical spine with condylar and articular eminence changes. The cases below demonstrate this capability.

#### Case 4

This 59 year-old white female was referred for evaluation of tooth site #14 for implant placement. In addition to chronic sinus changes and a failing implant at another site, the following images depict osteoarthritic changes of the

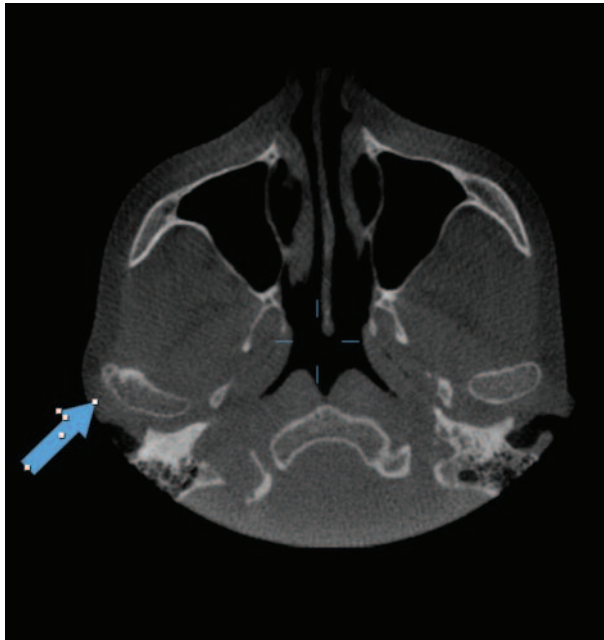
right TMJ condyle and certain vertebral bodies.

Osteoarthritis (OA) is a common finding in adults and clinicians placing implants and possibly altering the patient's occlusion should always image the TMJ complexes to rule out preexisting problems like OA to ensure success of their case restoratively. In addition, orthodontists are justifying scanning patients in “adult orthodontic cases” to assess any joint problems which could alter the progress of their case.

#### Case 5

This 68 year-old white female was referred for a preliminary assessment for orthodontic treatment. This case demonstrates a bilateral occurrence of “loose bodies” or synovial chondromatosis.

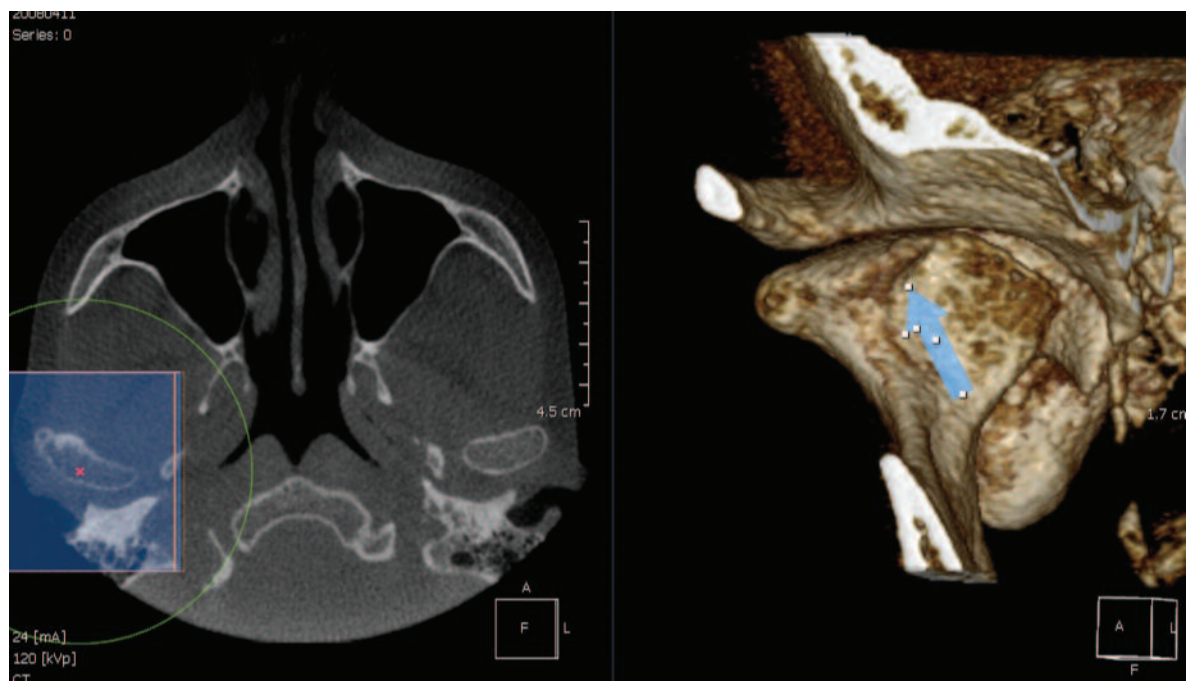




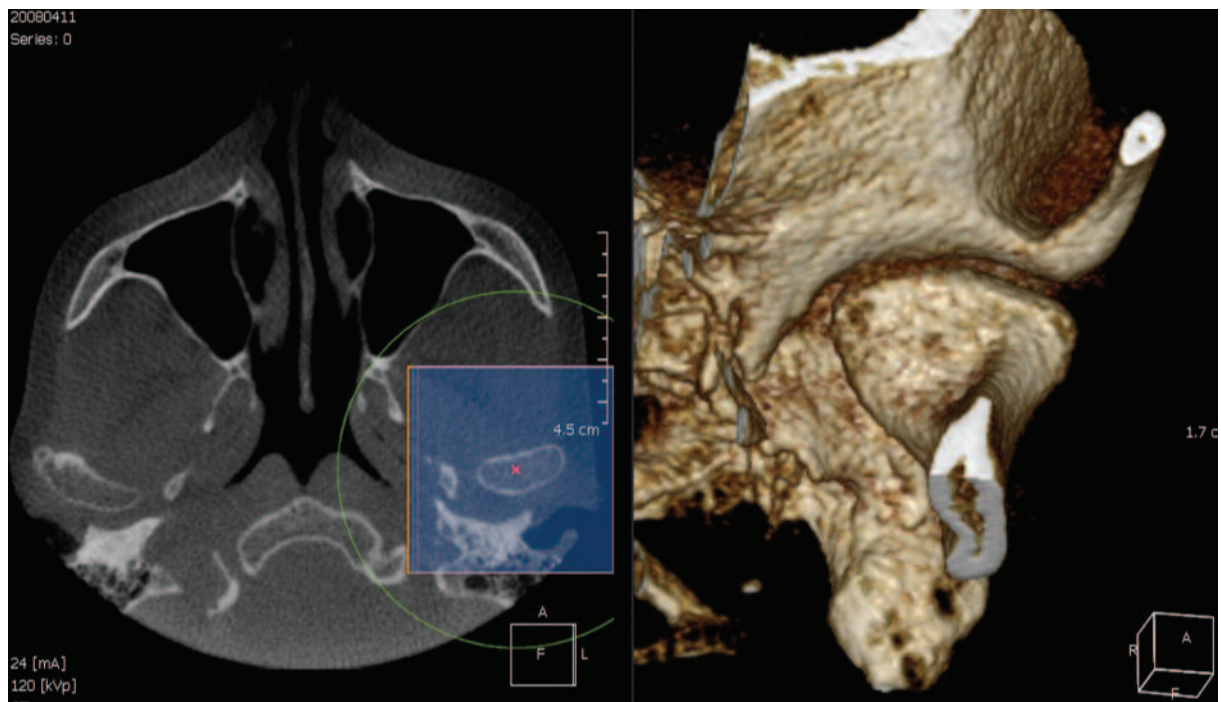
*Figure 4a: Axial "slice" through the mid-condyle region showing a "cystic lesion" on the lateral pole of the right condylar head (blue arrow).*



*Figure 4b: 3D color reconstruction of the right TMJ condyle and related bony elements showing the osteophyte formation and subchondral cyst on the lateral pole as well as some osteophyte formation on the anterior surface (blue arrows).*



*Figure 4c1: 3D color reconstruction of right TMJ complex.*



*Figure 4c2: The same process applied to the left TMJ complex for comparison showing a normal condylar head.*

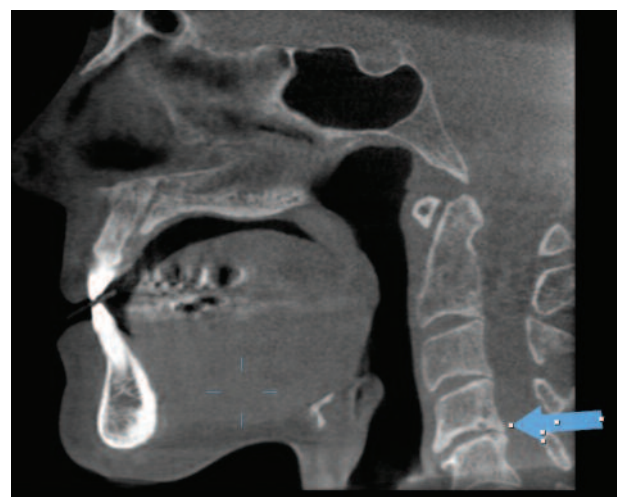
## Conclusion

In Part I of this article I've briefly discussed some current machines and common applications of CBCT. This part, called "the Ecstasy", used many cases to illustrate the power of these images for clinical decision making. The reader simply needs to look at the axial views and 3D color reconstructions to know that this technology will help them in their dental practice. Each picture is, for the most part, worth 1000 words. In part II of this series, I will present the downside of this technology: "The Agony." That is, the need for additional education if you're going to adopt cone beam imaging and the absolute need for a formal radiographic report from an oral & maxillofacial radiologist or medical radiologist with most cases.

## Disclosure

The author reports no conflicts of interest with any products mentioned in this article.

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*Figure 4d: Midline sagittal view of the vertebral column showing osteophyte formation, subchondral sclerosis and subchondral cyst formation on C4 and C5. These images confirm osteoarthritis of the C-spine and TMJ condyles.*

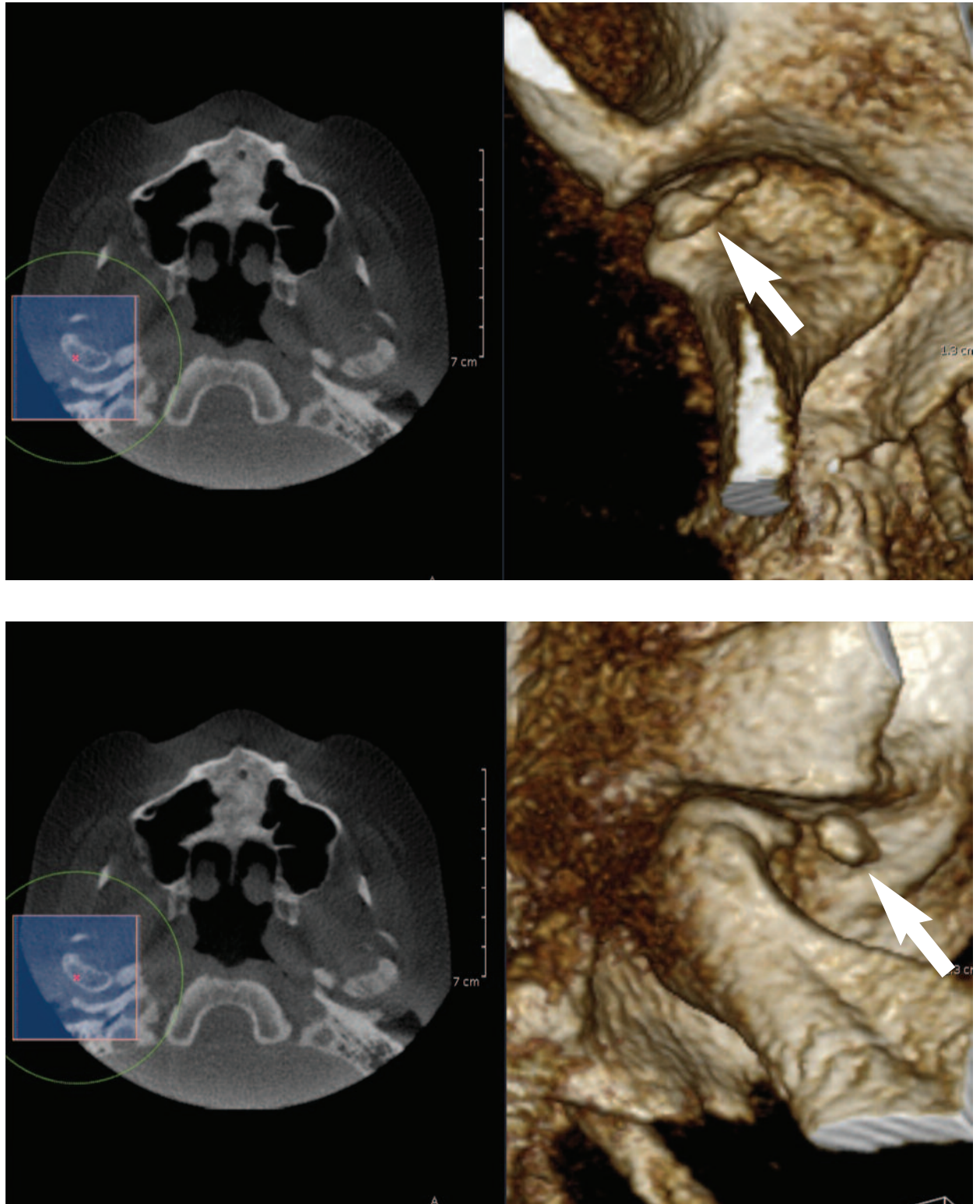
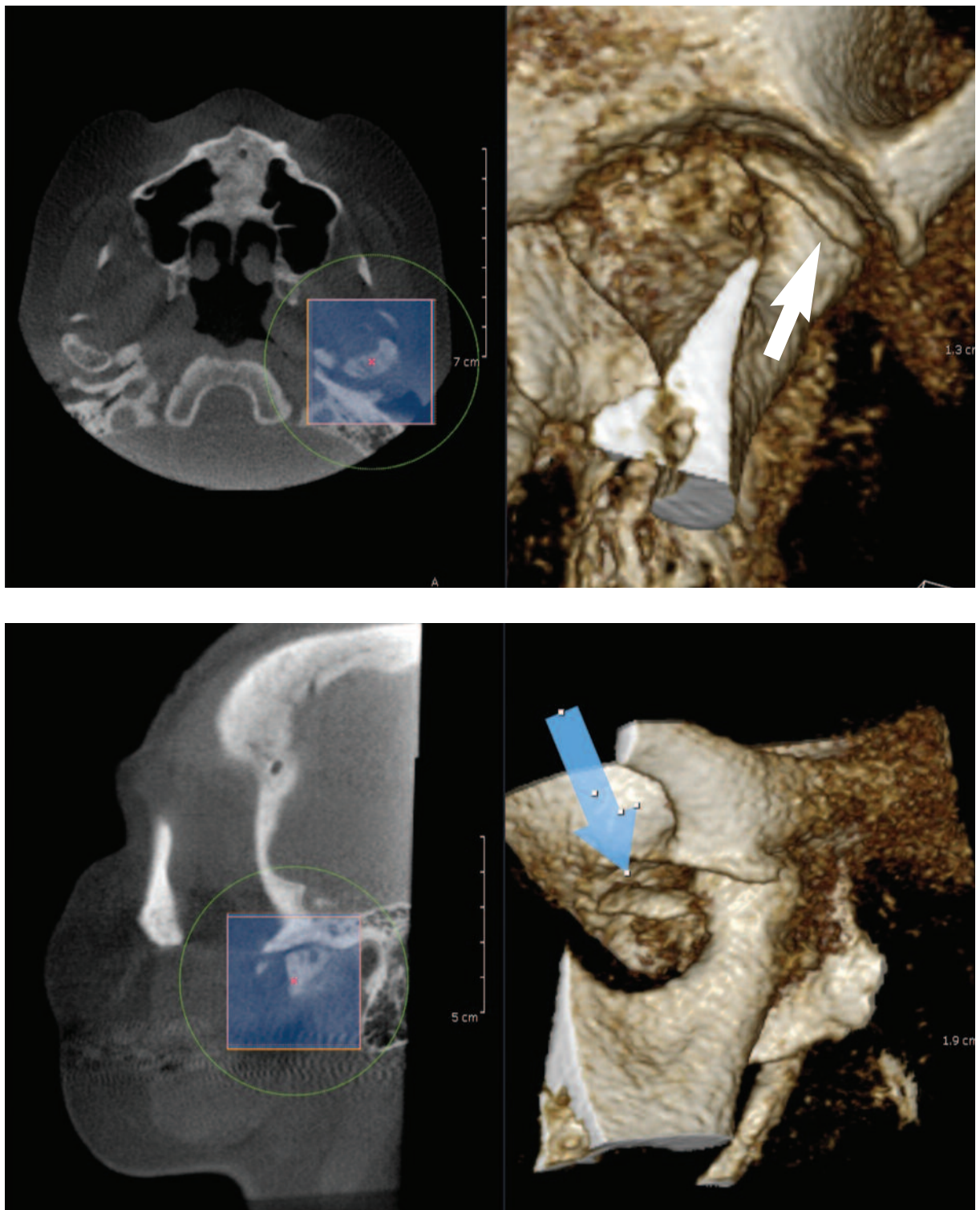
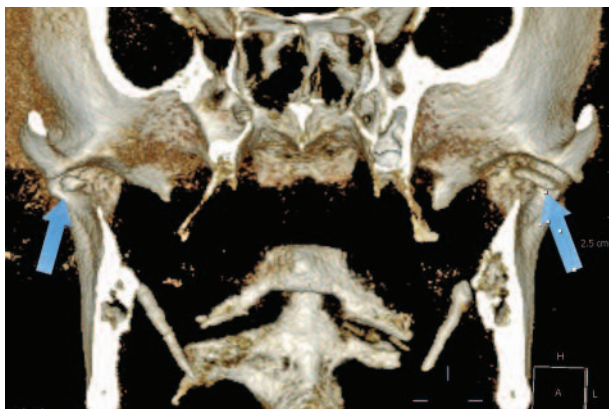


Figure 5a: A-P (top) and sagittal (bottom) image 3D color reconstructions of the right TMJ complex showing the "loose body" anterior to the lateral pole of the condyle.

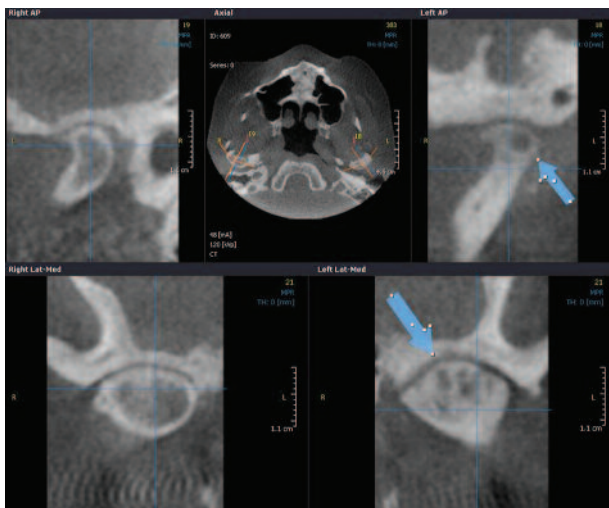




**Figure 5b:** A-P (top) and sagittal (bottom) 3D color reconstructions of the left TMJ complex showing the “loose body” anterior to the lateral pole of the condyle (white arrow, top image and blue arrow, bottom image).



**Figure 5c:** A-P 3D color reconstructions of the right and left TMJ complexes showing the “loose body” anterior to the lateral pole of the condyle (blue arrows). Note also the calcified elongated stylohyoid ligaments.



**Figure 5d:** Side-by-side comparison of the right and left condyles in the “TMJ” program showing subchondral cyst formation in the condylar heads.

## References

1. Danforth R, Mah J. 3-D Volume for Dentistry: A New Dimension. CDA Journal 2003; 31(11): 817-823.
2. Cattaneo PM, Melsen B. The use of cone-beam computed tomography in an orthodontic department in between research and daily clinic. World J Orthod 2008; 9(3): 269-82.
3. Miles D, Danforth R. A Clinician’s Guide to Understanding Cone Beam Volumetric Imaging. Academy of Dental Therapeutics and Stomatology Special Issue 2007; 1-13.
4. Nakajima A, Sameshima G, Arai Y, et al. Two and three-dimensional orthodontic imaging using limited cone-beam computed tomography; Angle Orthod 2005; 75: 895–903.
5. Scarfe W, Farman A, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Canadian Dent Assoc 2006; 72: 75–80.
6. Bourgeois M, Sikorski P, Taylor S. Cone Beam Volumetric Tomography. Oral Health 2007; 6: 14-16.
7. Miles D. Clinical Experience with Cone-Beam Volumetric Imaging – Report of Findings in 381 cases. US Dentistry 2006; 1(1): 39-42.
8. Danforth R, Miles D. Irish Dentist 2007; 10(9): 14-18.
9. Miles D: Color Atlas of Cone Beam Volumetric Imaging for Dental Applications. Quintessence. 2008: 47-303.
10. Miles D. The Future of Dental and Maxillofacial Imaging. Dent Clin N Am 2008; 52(4): 917–928.
11. Miles D, VanDis M, Williamson G, Jensen C. Radiographic Imaging for the Dental Team. SAUNDERS Elsevier, 4th Ed. 2008: 17-18.

**Dr Dale Miles is a keynote speaker at Vision Congress Jhb – 8 June 2012**





# The agony and ecstasy of buying cone beam technology

## Part 2: The Ecstasy

Dale A. Miles<sup>1</sup>

### Abstract

**Background:** This is the second article in a two part series that presents additional decision considerations when purchasing a cone beam computed tomography (CBCT) machine for use in dental practice. **Methods:** The author, a Diplomate of the American Board of Oral and Maxillofacial Radiology, draws upon his personal experience from interpreting over 3,700 CBCT scans to provide general and technical information on a number of CBCT systems. **Results:** CBCT scan volumes, CBCT scan information, range of interest (ROI), field of view (FOV), multifunctionality, and potential liabilities are discussed by the author. **Conclusion:** When considering the acquisition of a CBCT machine, one should evaluate a number of factors to make an informed purchase. Failure to consider these factors may result in a dissatisfied buyer and potential liabilities.

**Key words:** Cone beam computed tomography, digital radiography, radiographic image enhancement

### Introduction

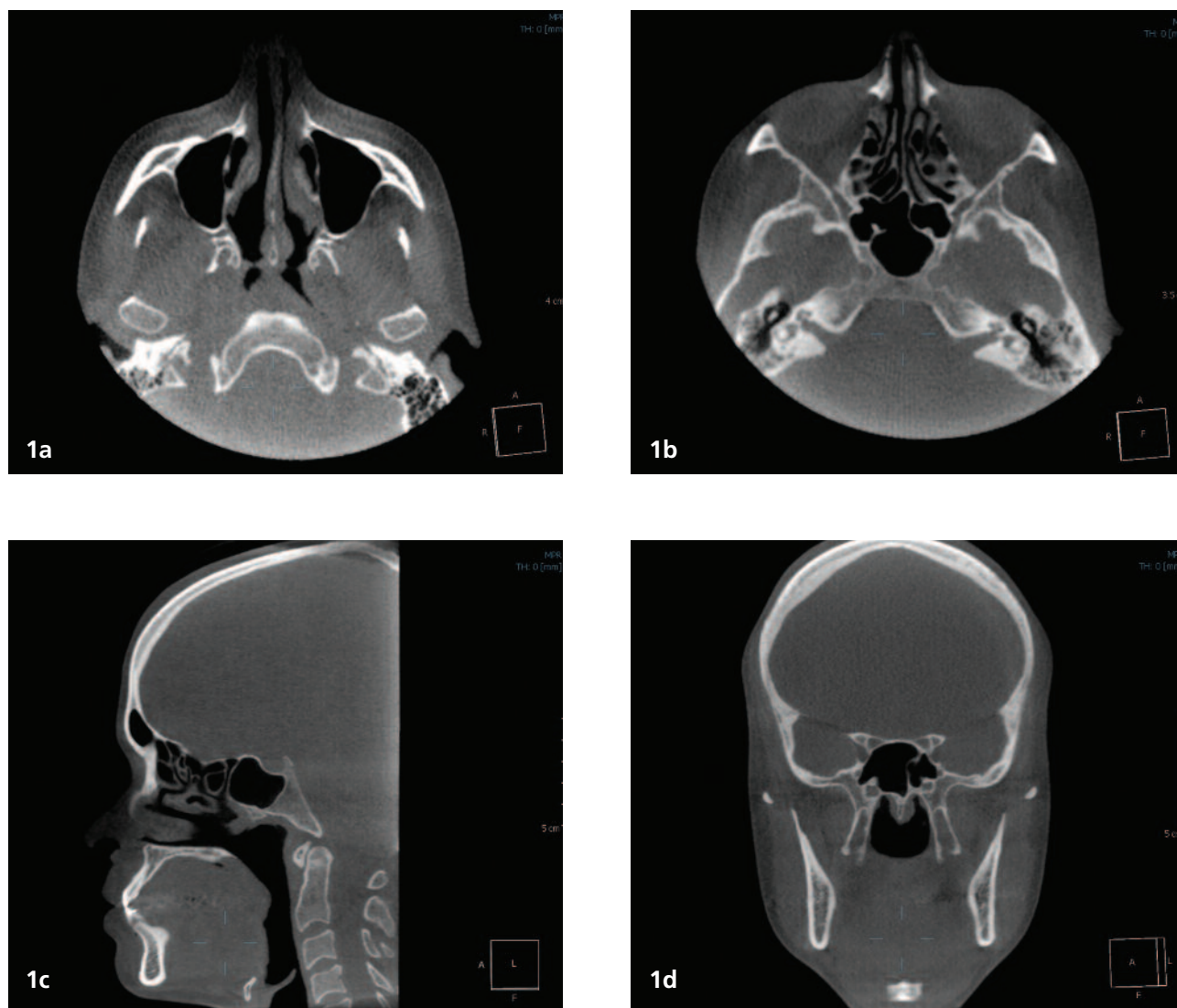
In part one of this two part article series, "The Ecstasy," I presented introductory information on cone beam computed tomography (CBCT) machines, the wide array of applications made possible by the incredible variety of image output choices, and some decision considerations for helping you decide which cone beam device might best suit your

practice. In the second installment of this series, I will provide you with additional "decision points" to consider when selecting the appropriate machine or service for your practice and some of the realities of adopting this technology related to: **1)** The amount of information in each scan volume; **2)** The types of information in each scan; **3)** The potential liability accompanying your purchase.

### Scan Volume Decisions

Initially, there was a marketing competition between companies that sold cone beam machines, with each making claims about the value of "large volume" machine advantages over "small volume" machines and vice versa.

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**Figure 1:** 1a. Axial slice of 346 slices at the level of the condylar head. 1b. Axial slice of the same patient slightly higher up in the scan at the level of the sphenoid sinus. 1c. and 1d. Sagittal and coronal slices through the sphenoid region.

Some claims, I feel, are valid, and some are not.

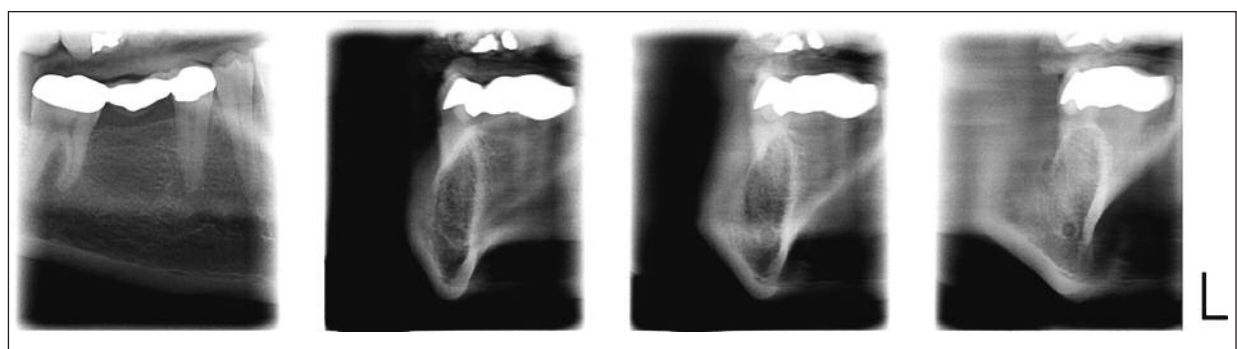
If you are an orthodontist and need to make measurements for various orthodontic analyses, you may require a large volume CBCT machine. Certainly, if the CBCT machine volume is 4cm x 4cm or less, for example, a small volume machine would not suffice if you do not have a cephalometric unit in addition to your cone beam machine. You would have to select a machine like the Imaging Sciences i-CAT (Hatfield, PA) or similar large Field of View (FOV) machine to capture your Region of Interest (ROI). Figure 1 shows some image areas captured by a "large" FOV machine.

However, if you had a machine that was *multifunctional*,

that is, one that can deliver a cone beam data set or volume, even if only 8cm x 8cm, and still retain the panoramic and cephalometric capability, then a machine like the Planmeca Pro-Max (Roselle, IL), the eWoo Picasso (Va-tech, Seoul, Korea) or Morita Veraviewepocs3D (Kyoto, Japan) could be advantageous. Initially, Planmeca was the only multifunctional machine and currently remains the only "upgradeable" x-ray machine on its existing platform. In addition to its panoramic and cephalometric capabilities, the ProMax CBVT 3D machine can also perform bitewing and periapical-like projections as well as selectable tomographic views of the TMJ and sinus regions. This is because of its unique technology: *SCARA – Selectively Compliant*



2a



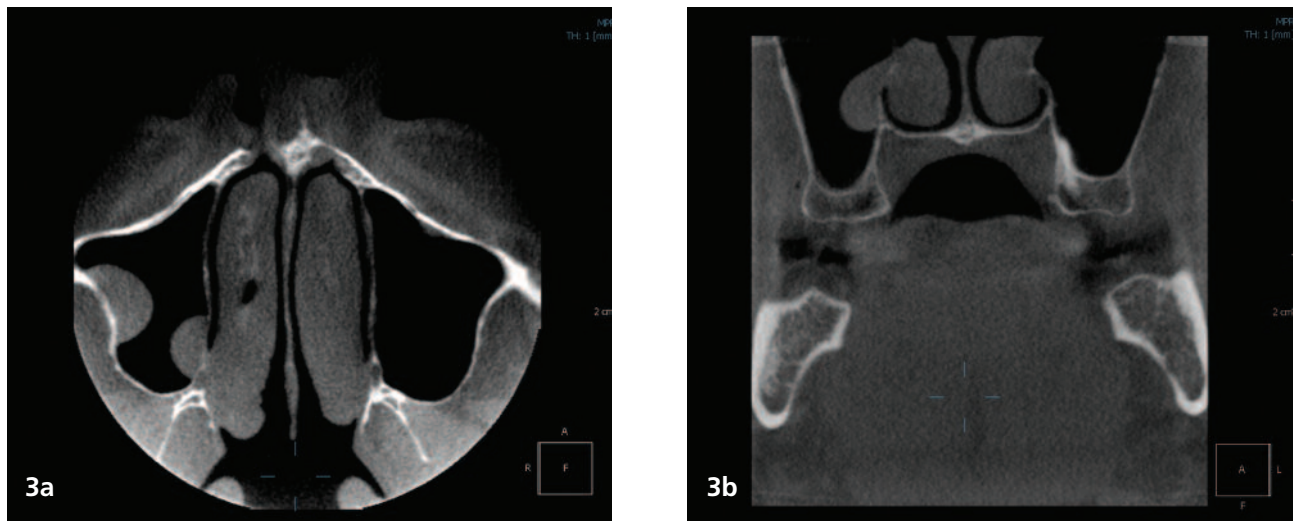
2b



2c

**Figure 2: Images acquired with SCARA technology. All images taken on a panoramic machine (ProMax, Planmeca USA, Inc, Roselle, IL). 2a. "Panoramic bitewing" radiograph; 2b. Implant cross-sectionals; 2c. Tomographic images of the left TMJ condyle.**





**Figure 3:** 3a. Axial slice of 500 slices at the level of the mid maxillary sinus showing 2 mucous retention cysts. 3b. Coronal slice near a posterior implant site showing the more medial mucosal lesion in the same patient possibly communicating with the inferior turbinate.

*Articulating Robotic Arm.* This SCARA technology (figure 2), coupled with a C-arm mounted on the top of the machine, is a patented “one-of-a-kind” device in the dental x-ray industry. The description of this technology is beyond the scope of this article, but its concept is what allows for all of the following, making this machine the most “multi-functional”: 1. True panoramic (not reconstructed from software); 2. True cephalometric image; 3. Tomographic views (TMJ, sinus and implant if desired); 4: Bite-wing views (large enough to see all periapices and at about 6 lp/mm); 5: Orthogonal panoramic view to see interproximal bone levels.

This concept of “multifunctionality” can be confusing with some claiming you can replace all dental imaging with cone beam technology. As in medicine, dentists need to preserve several types of imaging modalities and choices to assist their diagnostic tasks. Medicine certainly does not use or expect one radiographic imaging modality to cover all diagnostic tasks. Accordingly, the medical profession uses plain radiographic images, CAT scans, PET scans, magnetic resonance imaging (MRI), ultrasonography, and nuclear medicine scanning to assess their patient's problems. Dentistry is gradually moving in a similar direction, especially with cone beam technology and cone beam “multifunctional” machines.

To confound your decision-making, many “large volume” manufacturers claim that “you can do ALL of your imaging ONLY with a cone beam machine.” In my opinion, this is not true and should never be considered because of two factors I have previously discussed at length: namely, increased dose

to children and reduced productivity required for reconstructing an image like the panoramic.<sup>1-3</sup> A perfect example of this is monitoring the status of deciduous and permanent successor teeth in young children. When performing routine exams such as these, you must carefully weigh the risks of additional radiation exposure in obtaining CBCT volume sets when a simple panoramic image would suffice.

Figure 3 shows some “small” FOV images and images from multi-functional machines.

In these examples, the dentist, in most cases, would be skilled enough to interpret the antral findings. If nothing else, he or she would describe the lesions they found and refer the patient for an otolaryngologic evaluation. A simple description of the changes seen would suffice as long as it was accompanied by informing the patient and referring that patient to a specialist or back to their primary care physician for further evaluation. It is harder to see these changes in the first case/example (Figure 1) because of the increased area of coverage. Remember, you are not looking at a single image, but rather 300-500+ slices in 3 planes. The examination of these volumes, large or small, takes time.

With respect to the “large vs. small debate”, there seems to be a compromise on the horizon. Large volume manufacturers are moving towards a selectable FOV so that the operator can select a smaller region to fit the diagnostic task. Small volume manufacturers, on the other hand, appear to be getting ready to offer machines with large FOVs to attract customers like orthodontists who require larger areas for cephalometric analyses.

**Table 1: Common Reportable Findings on CBCT Scans**

|    |                                                                                                                                     |
|----|-------------------------------------------------------------------------------------------------------------------------------------|
| 1. | Paranasal sinus disease such as mucous retention cysts, chronic sinusitis and blocked ostia                                         |
| 2. | Enlarged adenoid and tonsillar tissues                                                                                              |
| 3. | Tonsilloliths                                                                                                                       |
| 4. | Deviated nasal septae and concha bullosa* (Figure 4)                                                                                |
| 5. | Calcified, elongated stylohyoid ligaments                                                                                           |
| 6. | Osteoarthritic changes on TMJ condyles                                                                                              |
| 7. | Osteoarthritic changes on cervical vertebrae                                                                                        |
| 8. | Missed dental conditions such as palatal root lesions, bone loss and implant perforations (usually because 3D imaging was not used) |
| 9. | Inferior alveolar nerve proximity to and contact of impacted third molars                                                           |

**Table 2: Significant Findings (number of cases in parentheses)**

|    |                                                                        |
|----|------------------------------------------------------------------------|
| 1. | Throat masses (4)                                                      |
| 2. | Vertebral tumors (2)                                                   |
| 3. | Fungus balls (aspergillosis), sphenoid sinus (2)                       |
| 4. | Odontogenic cysts and tumors (6-10)                                    |
| 5. | Calcified plaques and medial<br>arterial calcinosis (approximately 30) |
| 6. | Oro-antral fistulae (more than 5)                                      |
| 7. | Implant perforations (more than 20)                                    |
| 8. | Cranial tumors (2)                                                     |

**The Types of Information in Each Scan**

So what exactly is found in these scans? Back in late 2006, I published an article describing the findings of the first 381 cone beam volumetric cases I examined for various radiology laboratory services.<sup>4</sup> Even now, after interpreting almost 4,000 cases to date, I am impressed with the amount of “reportable pathology” in these data volumes. Table 1 lists the most common findings I have seen on the majority of scans I review while Table 2 lists some of the more significant findings that I have reported over the course of my career. It is important to evaluate the entire data volume. The number of significant and reportable findings I have seen over the years support this concept.

**Potential Liability**

One of the biggest misconceptions in the dental profession is who “owns” the liability if a significant finding is missed during interpretation of a CBCT scan. Some of this confusion can be attributed to a so-called “mock trial” held at the 108th annual session of the American Association of Orthodontists in 2008. Following the session of the “Doctor’s Risk Management Program”, Ms. Elizabeth Franklin, a claims manager for the AAOIC (American Association of Orthodontists Insurance Company) wrote the following:

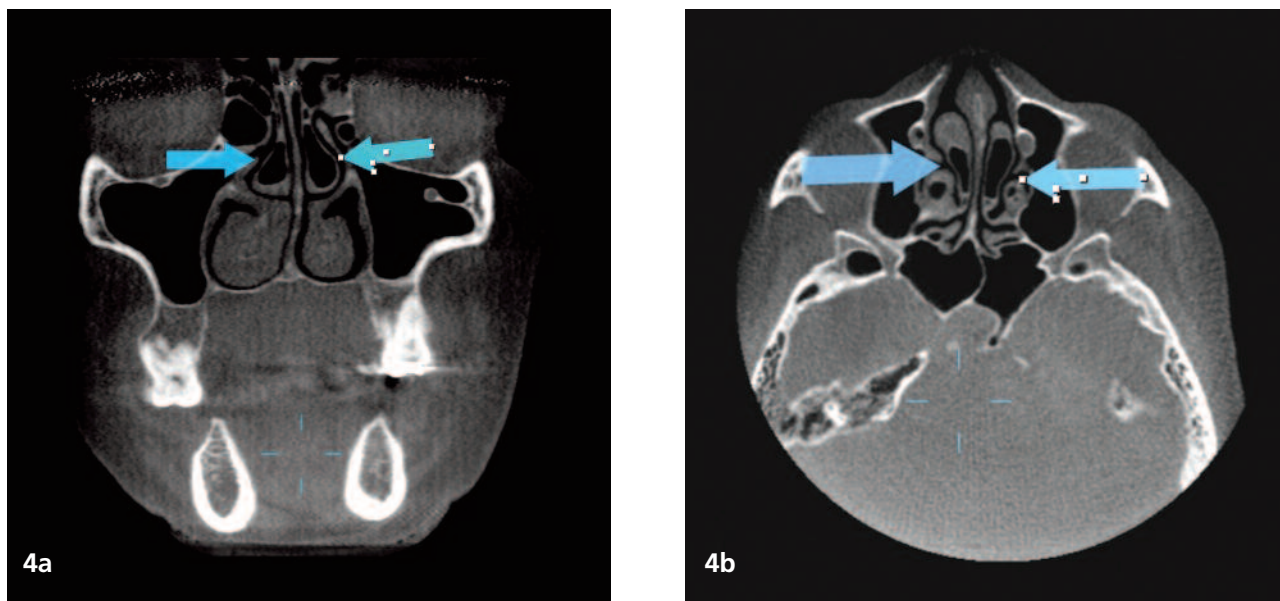


Figure 4: An example of the anomaly “concha bullosa” in the middle turbinates.

**\*Concha bullosa:** Aeration of the middle turbinate, termed “concha bullosa,” is a common anatomical variant of intranasal anatomy. Of 320 patients evaluated for sinus disease with coronal CT, 34% had concha bullosa on at least one side. The overall incidence of inflammatory disease in the ostiomeatal complex in these symptomatic patients was not different between those with and without concha bullosa. However, there were many cases in which an abnormally large middle turbinate appeared to obstruct the ostiomeatal complex causing secondary infection of the ethmoid, frontal, and maxillary sinuses. Obstruction of drainage of the concha bullosa itself can lead to mucocoele formation. Furthermore, the presence of a concha bullosa has important implications for the technique of endoscopic surgery used in the management of the sinus disease.

*“Cone-beam scans are a relatively new form of imaging available to the orthodontists to enhance patient treatment. Many orthodontists, however, are not trained to read three dimensional scans. If the scans are not read accurately and thoroughly, and incidental findings are missed, the orthodontist can assume a greater liability for failure to refer.*

*To protect from this exposure, the scans should be read by a trained practitioner.”<sup>6</sup>*

This is prudent advice. In a recent article by trial lawyer Mr. Kevin Henry,<sup>7</sup> at the 1st International Congress on 3-D Dental Imaging, California litigation attorney Arthur Curly, who specializes in medical and dental malpractice, informed dentists that:

*“Dentists and team members are not licensed to treat medical problems or any other issues outside of the oral cavity, so they are also not licensed to diagnose*

*conditions outside the oral cavity that are outside the scope of their dental practice. Therefore, dentists can recommend 3-D imaging as an option without fears that they could be liable for diagnosing everything seen on the image. They are only responsible for those areas that are within the scope of their practice, dentistry: jaws and oral cavity.”*

Unfortunately, some dentists have taken this to mean that they don't have to look at the data volume except as it pertains to their region of interest or the specific task for which they acquired the volume. If you read the assertion by Mr. Curly, someone has to look at all of the data. The prevalence of “occult pathology” is just too great.

For comparison, let's consider that you have had a preliminary chest x-ray taken to examine your heart for enlargement or hypertrophy of the muscle. Do you really think your physician or the radiologist would fail to look at the lung field as well in that chest film? By the same analogy,



you would never consider examining only half of a panoramic radiograph because only one lower third molar was thought to be present. Accordingly, why would you think that no one has to look at the entire cone beam data volume when only an implant site is being assessed? If the patient was harmed because you didn't look at the full data volume or have someone look at the data for you, it is my firm opinion that you may be facing a future lawsuit.

In the Spring issue of the North Carolina State Board of Dental Examiners Newsletter, 8 Dr. Clifford Feingold, the editor, stated:

*"It is the Board's understanding that some CBCT manufacturers emphasize that the machine may be used to evaluate a single region of interest (orthodontic planning for example), and that patient release/consent forms will absolve you from all responsibility from any outside specific narrowly tailored usage. This, of course, is a legal rather than a medical question and the Board urges you to consult your legal counsel for advice before risking exposure to potential liability. However, you should always remember that the Board views the use of CBCT under the rules applicable to radiographs. Therefore, if you acquire a volume of data, you should be able to interpret the data for a complete and accurate diagnosis."*

This, to me as a dentist and a radiologist, seems like a prudent approach. Just because the technique is new and novel, at least for dentistry, why would we NOT be responsible for interpretation of the data?

The first is that they are not comfortable with all the anatomy and potential pathology which may reside in the volume data. This is a legitimate concern and many colleagues have sought out specialists in oral and maxillofacial radiology to help them. The second is that they do not want to "pay" the added cost, or have the patient pay an "extra fee" to have a specialist look at the volume, because it might make the case "too costly" for the patient and the dentist might lose the anticipated procedure fee. This is self-serving and again, in my opinion, irresponsible behavior on the part of a dentist.

I even know of a colleague who has a patient sign a "refusal" document to have the cone beam volume read by a specialist. Regarding "informed consent" and "informed refusal" of care or treatment, a succinct explanation is presented in the May-June 2007 issue of The Reporter, a publication of the Texas Medical Liability Trust (TMLT). In this

issue, Ms. Jane Holeman, vice-president of Risk Management for the TMLT states the following:<sup>9</sup>

*"Implicit in and intrinsic to the concept of consent for treatment is the option of refusal. In Cruzan v Director, Missouri Department of Health, the U.S. Supreme Court ruled that all U.S. citizens have a constitutional right to refuse unwanted therapy, a right residing in the due process clause of the 14th amendment. Authorized surrogates can exercise this right of refusal on behalf of the incapacitated patients they represent. This right of refusal pertains to all therapies, including life-sustaining therapies and artificial hydration and nutrition, without which patients will die." All patients have the right, after full disclosure, to refuse medical treatment. This can include patients who decline medication, routinely miss office visits, defer diagnostic testing, or refuse hospitalization. Physicians are then prohibited from proceeding with the intervention. "Problems arise, however, when the patient or the patient's family later argues that they were not given enough information to make an informed decision, or that the patient lacked the capacity to make the decision..."*

The final part of this statement holds the key to this dilemma. How can a patient be expected to make an informed decision before they have all the information? If the scan volume is not interpreted and the dentist lacks ANY information about potential diagnoses and problems which might be in the x-ray data, that is the "occult pathology", how can the dentist say that he/she has fully informed the patient? The very thought that they've received informed consent from the patient, a dental and medical necessity, before all the information is evaluated and known is absurd. How can the patient give or sign their "informed refusal" without having knowledge of all of the information in the x-ray?

## Conclusions

Despite my rather sobering comments about the "Agony" of cone beam imaging, the interest, use, and adoption of this modality is welcomed by the dental profession. We benefit by better decisionmaking information, our patients benefit by more precise surgical placement of implants and better assessment of orthodontic, TMJ, and sinus problems in addition to suspected and unsuspected pathology. We can expect improvement in hardware, software, detectors and knowledge as they relate to this impressive and much

needed technology. In the end, we can continue to bask in the “Ecstasy” of Cone Beam Imaging, because it truly helps us all: both patient and clinician.

### Disclosure

The author reports no conflicts of interest with anything mentioned within this article.

*This article was previously published in The Journal of Implant and Advanced Clinical Dentistry.*  
[www.JIACD.com](http://www.JIACD.com)

### References

1. Miles D, Danforth R. A Clinician's Guide to Understanding Cone Beam Volumetric Imaging. Academy of Dental Therapeutics and Stomatology Special Issue 2007; 1-13.
2. Miles D. The Future of Dental and Maxillofacial Imaging. Dent Clin N Am 2008; 52(4): 917-928.
3. Miles D. Color Atlas of Cone Beam Volumetric Imaging for Dental Applications. Quintessence, Ch. 4-14 (pp 47-303), 2008.
4. Miles D. Clinical Experience with Cone-Beam Volumetric Imaging: Report of Findings in 381 cases. US Dentistry 2006; 1(1): 39-42.
5. Zinreich S, Mattox D, Kennedy D, Chisholm H, Diffley D, Rosenbaum A. Concha bullosa: CT evaluation. J Comput Assist Tomogr 1998; 12(5): 778-84.
6. Franklin E. “Doctor's Risk Management Program.” 108th annual session of the American Association of Orthodontists. Denver, Colorado: May 2008.
7. Henry K. 10 tips from a trial lawyer. Dent Economics 2008; 98 (6).
8. Feingold C. Cone Beam Imaging. The Dental Forum, NC State Board of Dental Examiners Spring 2007.
9. Brockway L. When Patients Decline Treatment: Informed Refusal. The Reporter, Texas Medical Liability Trust; May-June 2007.





# Temporomandibular joint imaging using CBCT: Technology now captures reality!

**Author\_** Dale A. Miles BA, DDS, MS, FRCO (C), Dip. ABOM, Dip. ABOMR

Over many years, dentists and dental specialists have moved from transcranial plain film images through tomography and conventional computed tomography (CT) as well as specialized panoramic imaging of the temporomandibular joint complex to arrive at cone beam CT (CBCT).

This latest imaging modality is making life easy for those clinicians who must evaluate the heart tissues of the temporomandibular joint complex in patients with orofacial pain.

Now, for the first time, we can actually visualize both pathology and anatomy in high-resolution, thin-slice, grayscale views; 3-D color-reconstructed views; and even more-detailed views using virtual endoscopy and robust third-party software.

No longer are we confined to "scout" film panoramics, linear or complex tomography or even high-dose, less-resolute conventional CT for visualizing the condylar head.

Radiographic interpretation of the temporomandibular joint complex, including the condyle, using CBCT imaging enables clinicians to find more subtle osteoarthritic changes, such as subchondral cysts, subchondral sclerosis, osteophyte formation, surface erosion and bony remodeling, consistently and with more certainty – to make their clinical decision-making simpler.

Let's now examine some of these osteoarthritic changes for which CBCT imaging makes their characterization easy.

## \_c.e. credit part X

This article qualifies for C.E. credit. To take the C.E. quiz, log on to [www.dtstudyclub.com](http://www.dtstudyclub.com). The quiz will be available on XXXX.

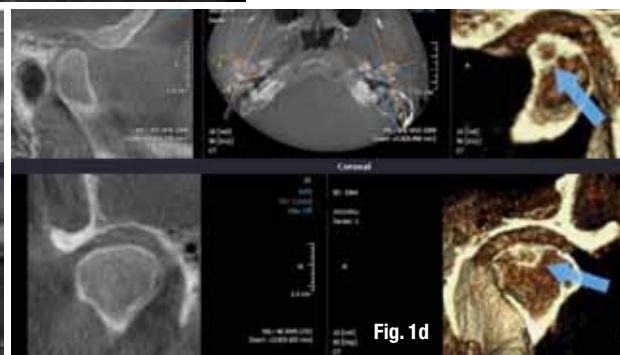
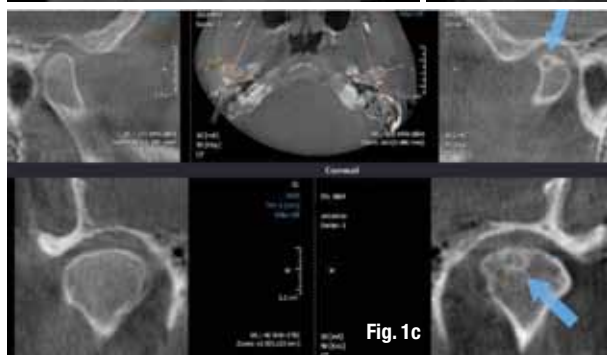


**Fig. 1a** Small circular radiolucency seen on the left condyle in the sagittal plane just inferior to the cortical margin. (Photos/ Provided by Dr. Dale Miles)

**Fig. 1b** The same lesion seen in the coronal plane of section. In this view it is more ovoid and appears to have a septation.

**Fig. 1c** The same lesion seen reformatted in the OnDemand3D software for a bilateral TMJ comparison. The right condylar head appears normal; the left reveals the same lesion seen in Figures 1a and 1b.

**Fig. 1d** Subchondral cyst formation visualization in thin slice (10 mm), 3-D reconstructed view.

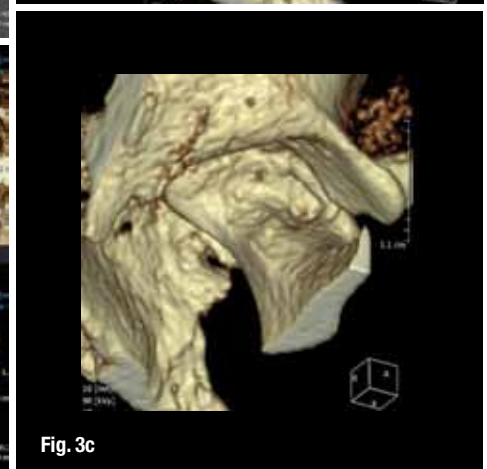
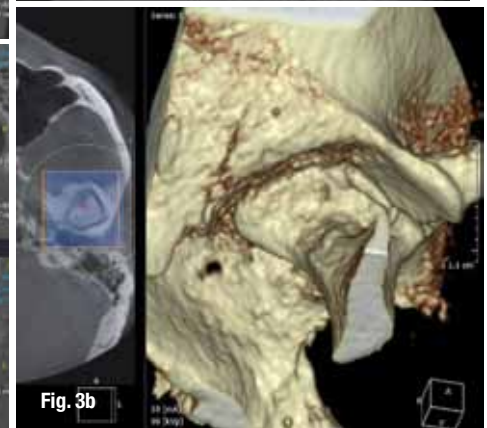
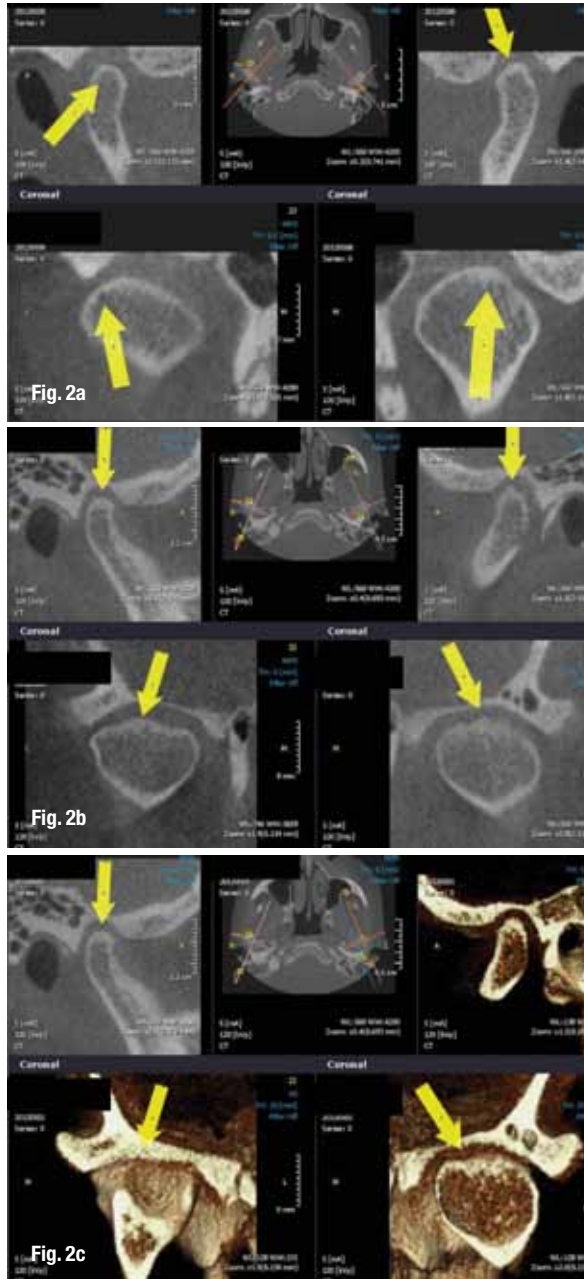


**Fig. 3a** A thin-slice (0.1 mm) sagittal view through the patient's left condyle showing a projection on the anterior surface of the condylar head.

In the past this would have been called a "bird beak." This appearance along with the loss of joint space would seduce the clinician into calling this osteoarthritis.

**Fig. 3b** Using a "cube tool" in a third-party software called OnDemand3D (CyberMed, Irvine, Calif.), a 3-D color reconstruction confirms that there is a deep pterygoid fovea and significant "lipping" on the anterior aspect of the condyle. There is no bird beak.

**Fig. 3c** A close-up of the 3-D color reconstruction, slightly rotated, to help the clinician visualize the true morphology of the condylar head.



Dr. Miles:  
Image 3c  
cannot be  
made any  
larger

## Subchondral sclerosis

### Subchondral cyst formation

Subchondral cyst formation is an early indicator of osteoarthritic changes in the joint surface. I cannot honestly say that I have a good example of a subchondral cyst, even after 35 years of looking at panoramic and other TMJ images using tomography or other plain-film techniques.

However, having looked at more than 12,000 CBCT scans, I can easily identify such cysts and embed images of them into reports that I produce for my clients. Figure 1 demonstrates examples of subchondral cyst formation.

Subchondral sclerosis is an increased intensity or thickening of the cortex below a cartilaginous surface. It can occur on the condylar head or on the opposing surface of the glenoid fossa. It is often seen in conjunction with subchondral cyst formation.

Loss of joint space, subchondral sclerosis and subchondral cyst formation are considered the radiographic hallmarks of osteoarthritis.

In long-standing rheumatoid arthritis there is also a tendency for the joint surface, especially in the TMJ complex, to exhibit sclerotic change. This cortical alteration has been identified in the past on conventional panoramic images, either on film-based

images or with newer digital, solid-state detectors.

### Lipping

The formation of a liplike structure, as at the articular end of a bone in osteoarthritis (source, [www.biology-online.org/dictionary/lipping](http://www.biology-online.org/dictionary/lipping)).

With older imaging modalities, we often spoke of a “bird beak” appearance, which was indicative of an osteophyte and/or osteoarthritic change. With 3-D color CBCT imaging we now see that there are very few “bird beaks.”

Tomography, transcranial and panoramic views used in the past underestimated some of the changes and gave a false appearance depending on the slice thickness or lack of view of the condyle from a truly lateral perspective. Figures 3a through 3c demonstrate the past problem in the future solution.

### Surface erosions

Surface erosions are also common features in osteoarthritis. Until now these changes have been more difficult to demonstrate on the TMJ condyles. However CBCT imaging, especially 3-D color reconstructions, enables the clinician to visualize these smaller surface changes like never before.

### Condylar comparison

When a patient presents with orofacial pain, which the clinician suspects to be related to the temporomandibular joint condyles, it is imperative to compare both sides. This is slightly more cumbersome with smaller field-of-view (FOV) machines because two views of the condyles are necessary and must be acquired separately.

If evaluation of patients with orofacial pain is a large part of the dental practice, a larger FOV CBCT machine may be indicated. A single image acquisition allowing comparison of both sides while evaluating a single volume is probably a more preferable arrangement for this patient population.

It is much easier to compare the condyles in a single multiplanar view or in specialized CBCT temporomandibular joint views as seen in the images presented here.

### Conclusion

As you can see from the examples shown, conditions such as osteoarthritis can be easily evaluated and visualized completely with thin, grayscale multiplanar images, thickened-slice data and 3-D color reconstruction.

Almost all pathology can be evaluated or visualized as it truly exists within the patient. This visualization was unachievable with all of the previous imag-



Fig. 4a

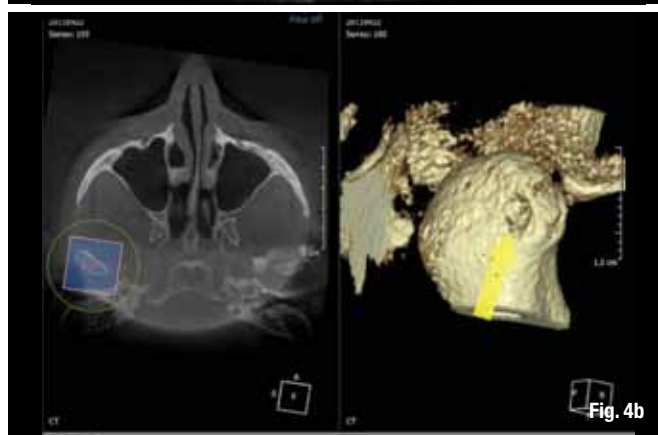


Fig. 4b



Fig. 4c

**Fig. 4a** Radiolucencies on each condyle near the lateral pole suggestive of erosions.

**Fig. 4b** 3-D color reconstruction using the “cube tool” confirms presence of a surface erosion on the condyle just posterior to the lateral pole.

**Fig. 4c** This 3-D color reconstruction also employs a “virtual endoscopy tool,” which allows an even more detailed visualization of this erosion and subcortical defect.



## Dr. Miles: Images 5b, c cannot be made any larger

**Figs. 5a, 5b** Thin-slice sagittal view showing a hypoplastic left condyle relative to the right.

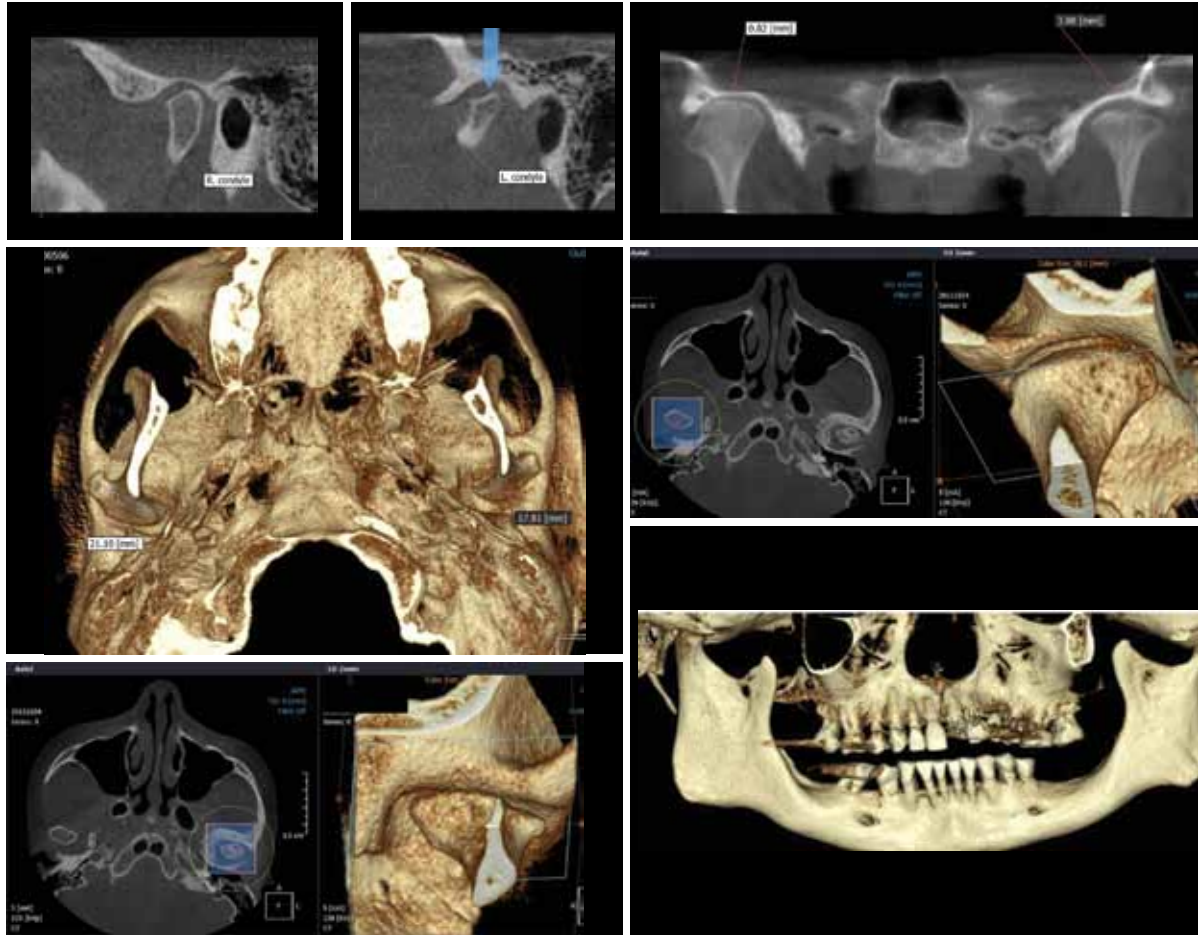
**Fig. 5c** The 8.6-mm-slice thickness showing hypoplastic left condylar head with a possible surface erosion. There also appears to be less joint space on the right.

**Fig. 5d** Three-dimensional color reconstructed view comparing the condylar heads. This was done in the slice thickness of about 40 mm. Measurements of the condylar width are within 0.1 millimeter accuracy.

**Fig. 5e** Three-dimensional color-reconstructed view of another patient's right condyle. Note the subchondral cyst formation and subchondral sclerosis in the left condylar head in the axial slice on the left.

**Fig. 5f** Three-dimensional color-reconstructed view of the left condyle of the patient seen in Figure 5e. This condyle is obviously remodeled and hypoplastic relative to the right.

**Fig. 5g** Three-dimensional color-reconstructed panoramic view showing the hypoplastic left condyle. However, this is only part of the patient's hypoplasia problem, because the ramus is smaller in the posterior sending ramus a shorter. These changes would not be as apparent on a conventional panoramic image. Nor would the patient's periodontal bone loss be as easily assessed.



ing modalities used in dentistry. In addition, we can make our terminology more precise when describing these changes because we can see the condyles in color in 3-D.

More complex situations, such as the unilateral condylar hypoplasias shown in Figure 5g can also be easily visualized and compared using the many tools

and features in third-party CBCT imaging software.

If the clinical signs and symptoms warrant a CBCT evaluation of the patient, the clinician will be rewarded by easier visualization of the anatomy and pathology as well as more precise clinical decision-making because of the excellent images available with this imaging modality.

## \_about the author

## cone beam



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# Cone beam volume imaging (CBVI) 3D applications for dentistry

Robert A Danforth and Dale Miles discuss the impact of cone beam volume imaging on dentistry

The hallmark of dentistry in the new millennium is 'computer assisted dentistry' and nothing characterises this more than the impact 3D cone beam computed volume imaging/tomography (CBVI/CBVT) has had upon diagnosis, treatment planning and direct delivery of patient dental care.

In less than a decade, CBVI has revolutionised oral and maxillofacial radiology. Although development was initially directed towards multi-planar viewing for dental implant and orthodontic treatment planning, secondary applications in other areas continue to expand because dentists find they are no longer confined to 2D, greyscale imaging and it provides information previously unobtainable (see Table 1).

The intent of this article is to provide a brief overview of

dental CBVI technology and examples of applications. While this technology has been almost universally described as CB computed tomography (CBCT), use of this term associated with the introduction of this

technology created some concerns that this was in reality a medical device and, as such, should not be directly available to dentists for operation. This was particularly a concern in the USA and various terms such

as CBVI or CBVT were used to differentiate this connection with medical CT. In this article, CBVI is used to continue the differentiation.

Descriptions of CBCT devices for dentistry first appeared in the late 1990s with reports from Italy and Japan describing the development of prototype machines (Mozzo P et al, 1998; Arai Y et al, 1999). The first devices to become commercially available were the Newton QR 9000 (QR Italia, Verona, Italy) and the 3DX Accuitomo (J Morita, Kyoto, Japan), which were initially introduced into the European and Asian markets. These were soon followed by the MercuRay (Hitachi, Japan, Twinsberg, OH, USA) and the i-CAT (Imaging Sciences, Hatfield, New Jersey, USA). All of the devices are capable of providing complete or partial skull fields of view (FOV) except for the 3DX Accuitomo, which is a regional quadrant device with a field size of 40 x 30mm.

Currently, there are approximately a dozen different machines either available, receiving government approval or in development (see Table 2). Some of the recent machines have specifically targeted a limited FOV favouring regional, quadrant and dental arch imaging similar to the initial Accuitomo device. Such an approach appears directed toward providing cost-effective 3D imaging for the general practice market (Farman AG, Levato CM, Scarfe WC, 2007; Miles DA,

**Table 1: Current dental applications of CBVI**

**1. Primary applications**

- Pre-surgical implant site assessment
- Inferior alveolar nerve location
- Alveolar ridge configuration
- Spatial relationships of anatomical structures
- Surgical guide construction
  
- Orthodontic assessment
  - Cephalometric and space 1:1 analysis
- Temporomandibular joint evaluation
  - Multi-planar views, dentition relationship
- Extraction cases
  - Impactions, third molars/nerve location, canines
  - Supernumerary teeth

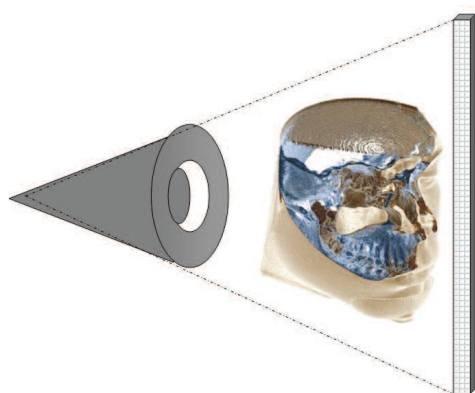
**2. Secondary applications**

- Paranasal sinus evaluation
- Airway studies for sleep apnoea
- Visualisation of jaw pathology
- Trauma evaluation
- Endodontic evaluation
- 3D virtual models
- TADs (Temporary anchorage devices)
- Other CAD/CAM devices

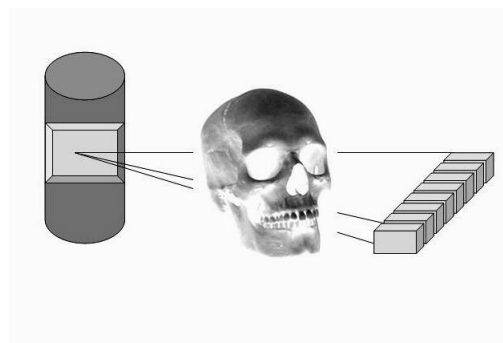
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*Dale Miles DDS, MS, FRCD(C) is a Diplomate of the American Board of Oral and Maxillofacial Radiology and an Adjunct Professor at the Arizona School of Dentistry & Oral Health and the University of Texas at San Antonio.*





**Figure 1a: Cone-shaped beam rotates about head once**



**Figure 1b: Fan-shaped beam rotates about patient's head hundreds of times, acquiring thin horizontal or axial sections**

Danforth RA, in press; Hayakawa, 2007).

### How does it work? Why is it a better option for dentistry than medical computed tomography (CT)?

Most of the CBVI 'stand-alone' devices look like a panoramic machine and the patient either sits or stands during the examination. By contrast, the NewTom 9000, NewTom 3G and the newer SkyView machines look like mini medical CT scanners and the patient lies in the supine position. However, the newest version of the Newtom VG, marketed by Dent-X/AFP, will be a stand-up version. While some companies have previously produced panoramic machines, currently only the Planmeca ProMax CBVT is actually 'upgradeable' from an existing panoramic platform.

Depending upon the imaging device, image

capture is generally a single 190°-360° scan sweep around the patient's head. The X-ray beam is a 'cone beam' shape aimed at a solid-state flat panel detector that covers the desired image volume in a single scan. The 'fan-shaped beam' employed in traditional medical CT requires multiple repeated slice scans to accomplish a similar image volume (Figures 1a and 1b).

This single scan CBVI approach is very successful at decreasing the patient's absorbed X-ray dose from six to 15 times during the 3D imaging examination when compared to medical CT (Farman AG, Levato CM, Scarfe WC, 2007).

The cone beam scan results in several hundred dimensionally accurate isotropic images of the patient from different positions around the scan rotation. Data is immediately transferred to the computer,

which reconstructs it, in approximately three to six minutes depending upon the machine, into the anatomical volume for viewing at a precise 1:1 ratio with accurate dimensional measurements within 1/10mm made across different tissue planes.

Once reconstructed, multi-planar viewing of the anatomical volume is accomplished with the imaging software. Volume data is saved in a DICOM (Digital imaging and communication in medicine) file format to facilitate sharing images between clinicians and other imaging related services.

Most manufacturers also provide a simpler 'user' PC viewing program that contains basic 3D imaging tools. This allows referral sources to participate in limited 3D imaging without having to purchase expensive software. For clinicians who wish to plan their implant cases more actively, third party software is available at a wide range of cost.

### Applications and a new perspective for interpretation, diagnosis and treatment planning

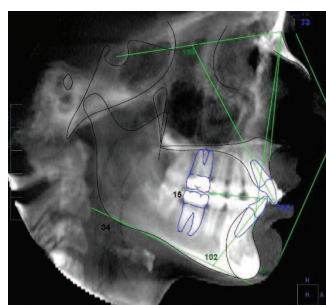
The results of computer-generated 3D visualisation of multi-planar images are new applications that improve interpretation, diagnosis and treatment planning.

Imaging for orthodontic

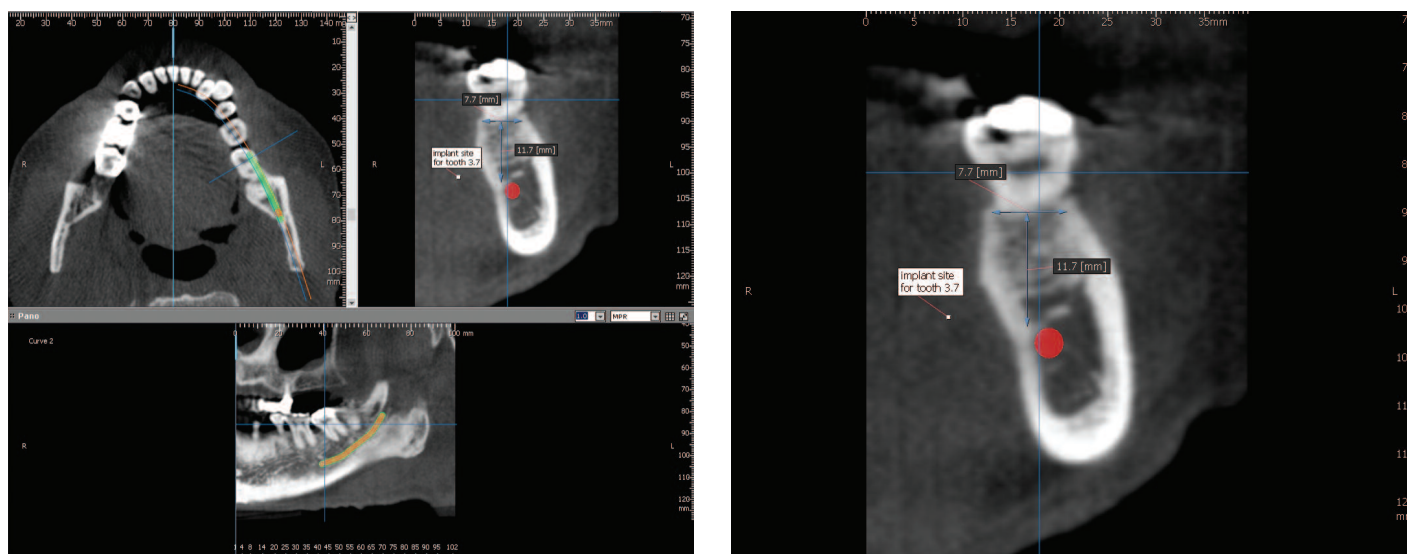
## Table 2: CBVI devices and manufacturer 2007

1. NewTom 3G, VG: Dent-X, Elmsford, New York, USA
2. Accuitomo 3DX: J Morita, Kyoto, Japan
3. i-Cat: Imaging Sciences (Danaher owned), Hatfield, Pennsylvania, USA
4. CB MercuRay, CB Throne: Hitachi Medical Systems, Twinsburg, OH, USA
5. Iluma: Imtec Corporation (Kodak distribution), Ardmore, Oklahoma, USA
6. Galileos: Sirona Dental Systems, Bensheim, Germany
7. ProMax 3D CBVI: Planmeca, Helsinki, Finland
8. SkyView: MyRay Dental Imaging, Imola, Italy
9. TeraRecon: Yoshida Dental Manufacturing, Tokyo, Japan
10. Alphard and PSR900N: Asahi Roentgen, Kyoto, Japan
11. Scanora 3D: Soredex (PaloDex), Tuusula, Finland
12. PicassoPro: eWoo (Gyeonggi-do, Korea)

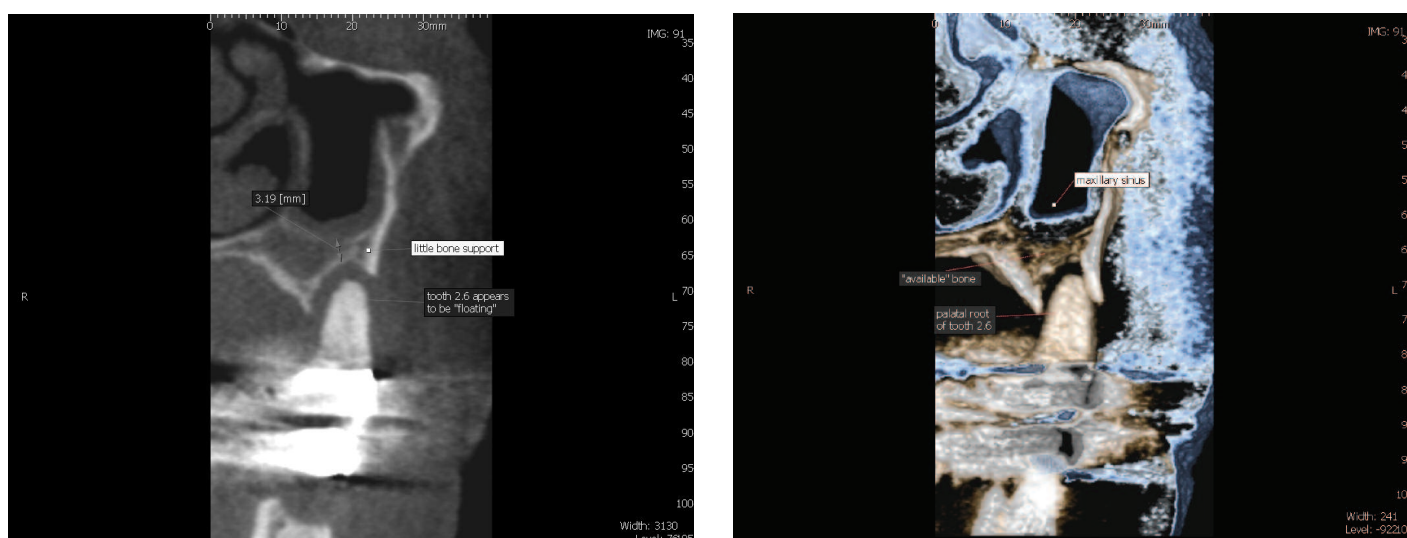
**Figures 2a and Figure 2b: Lateral cephalometric Images made using Multiple Image Planes (MIP). Figure 2a (left) shows MIP Images with soft tissue profile and Figure 2b (right) shows an image with orthodontic measurements using software developed for CBVI**



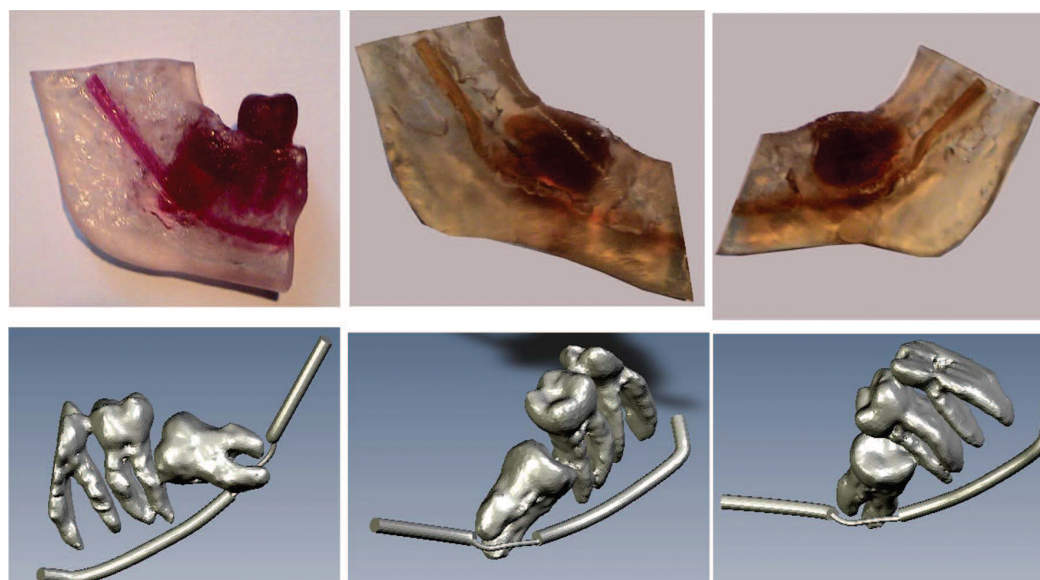
## CLINICAL



**Figure 3a: Analytical image to render inferior alveolar canal structures visible in colours and precise Implant site measurements. The proposed Implant fixture may now be placed without fear of impinging on the inferior alveolar nerve**



**Figure 3b: Proposed Implant site of tooth to be extracted showing insufficient bone, periapical disease and associated inflammatory changes in maxillary sinus. Clearly, there is other treatment necessary before even attempting placement of an endosseous Implant in this site**



**Figure 4:**  
**Top row: reconstructed laser-generated resin models from CBVI volume images to assist surgical treatment planning for impacted third molars at risk of injury to the inferior alveolar nerve**

**Bottom row: visual models segmented from CBVI image data. Interactive tools allow for rotation, measurements and image 'slicing and dicing' to assist surgical planning**



the orthodontic 1:1 ratio cephalometric measurements for treatment planning and several software programs have been developed for this purpose (Figure 2).

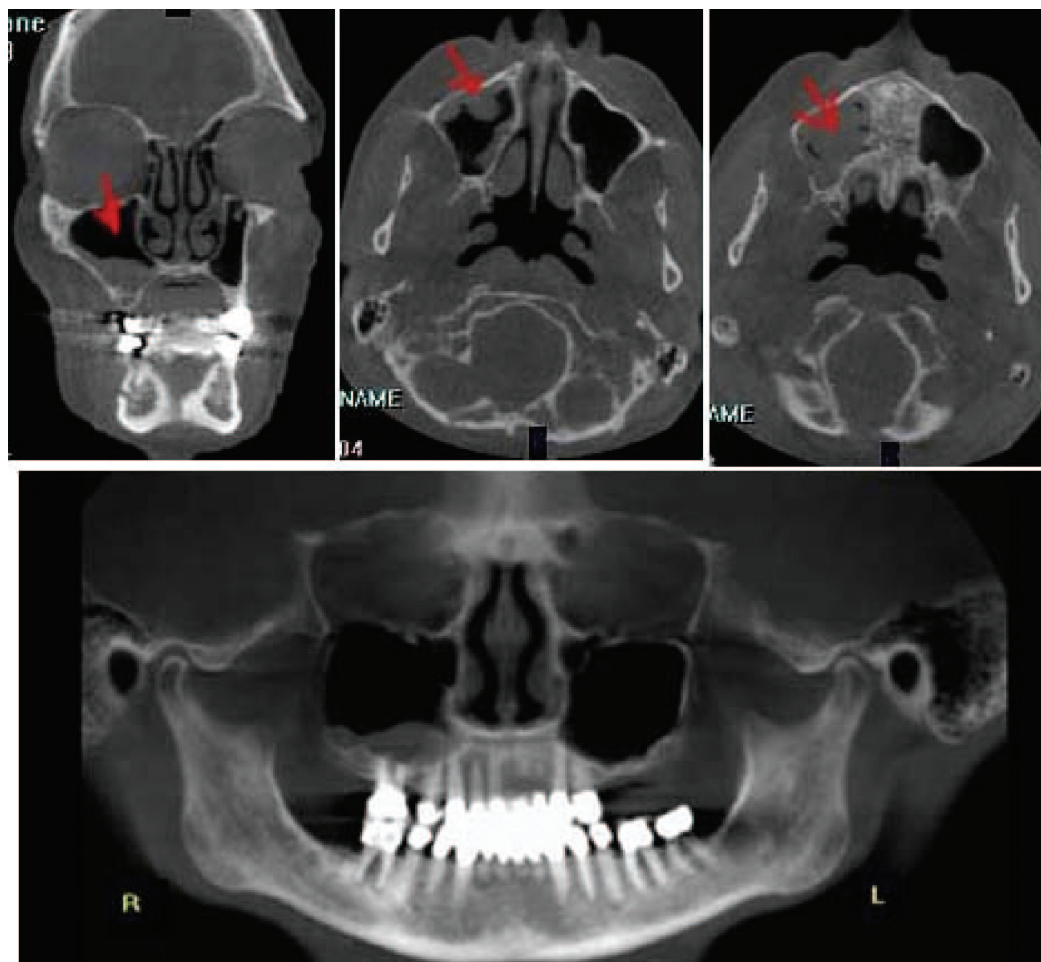
There has also been a tremendous impact upon dental implant treatment and treatment planning. Arch and ridge configuration, location of the nerve canals and sinus cavities can now be specifically identified prior to surgery, thus decreasing surgical uncertainty and potential patient morbidity (Figures 3a and 3b).

Besides mere visualisation of cross-sectional imaging of jaw site locations, innovative software programs have been developed to make custom precision surgical guides, virtual models and laser-generated resin models, all of which advance treatment planning and assist delivery capabilities (Figure 4).

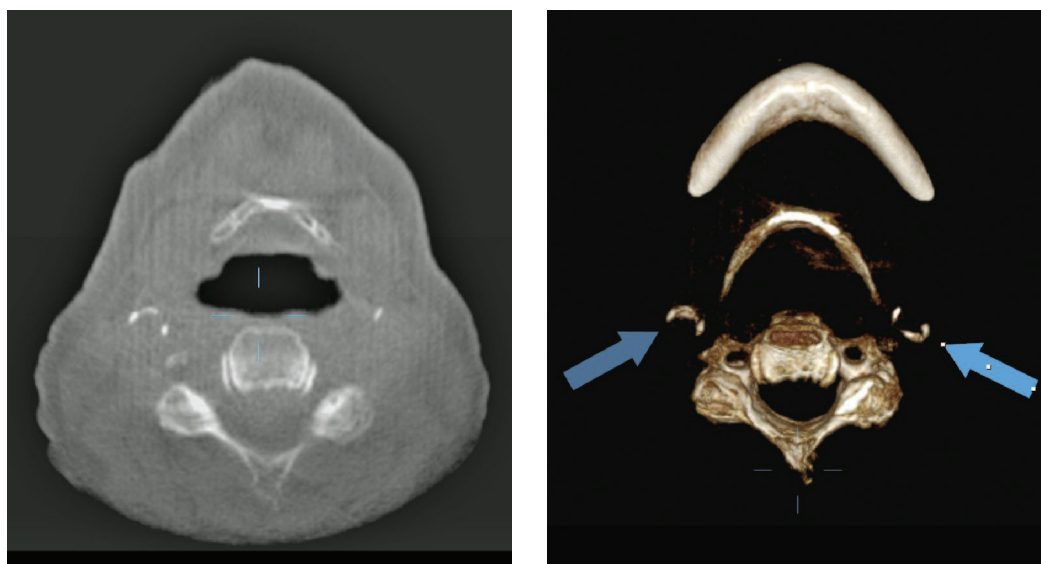
The advantage of these innovative changes is that they are relatively cost-effective and readily available to the dentist. Direct fabrication of dental appliances from CBVI data using CAD/CAM (computer assisted design/computer assisted manufacturing) systems would seem a next progressive development.

### Beyond dental – 3D image volume produces new interpretation responsibility

Although CBVI has created exciting new 3D methods for dental applications, it has also created increased responsibility for image interpretation. Unlike superimposed 2D imaging, a large volume of viewable collected patient data exists outside of the specific region of interest (ROI) in the multi-planar sections. Such image data must be viewed in the X, Y and Z planes to ensure that a comprehensive evaluation has been performed and documented (Miles DA, 2006). Failure to recognise these or to act upon them could result in various pathologic conditions going undetected that could



**Figure 5a: The extent of right maxillary sinus disease is shown using multiple plane reviewing and a reconstructed panoramic image. Use of such techniques better defines the location of the disease and any impact it may have on the proposed treatment plan**



**Figures 5b and 5c: Bilateral circular calcifications in the region of the carotid sheath at the level of C3/C4 consistent with MAC (medial arterial calcinosis) seen in diabetic patients especially with end-stage renal disease (ESRD)**

have a negative outcome on either the provided treatment or, worse, patient health and longevity.

Table 1, part 2 indicates that sinus and airway are applications for evaluating the presence of conditions

involving pathologic lesions, sleep apnoea or head and neck artery calcifications. In some cases, these may be



## CLINICAL

secondary/incidental but life-threatening findings that are most likely located outside the jaws in non-ROI 3D multi-planes. As such, many dentists may not be as familiar or comfortable with looking for or interpreting these conditions.

Despite any unfamiliarity, many recent reports (Friedlander AH, Garrett NR, Norman DC, 2002; Miles DA, Craig RM, 1983; Almog DM et al, 2002; Magliocca KR, Helman JI, 2005; Kumar V et al, 2007) indicate dentistry has a role in such conditions as:

- Airway sleep apnoea problems
- Sinus conditions
- Bisphosphonate jaw osteonecrosis
- Awareness of carotid and other arterial calcifications as an indicator of potential stroke or advanced diabetic/renal problems.

These are examples of expanded regions of concern and responsibility where CBVI can assist detection of these conditions. In these circumstances, referral to a diagnostic imaging radiologist/specialist for an interpretative report of the 3D data volume is recommended (Figures 5a, 5b and 5c).

### Conclusion

Any clinician reviewing the application list in Table 1 knows the limitations imposed by 2D imaging in a 3D world when interpretive diagnostic dilemmas arise in these areas. The length of the list indicates that, actually, no aspect of dentistry is free from such dilemmas. Until CBVI, when confronted with such situations, clinicians either chose medical related CT imaging or continued to

rely upon their traditional interpretation of 2D imaging despite inherent disadvantages.

CBVI imaging provides relief for clinicians from 3D mental reconstructions by using outstanding computer-assisted 3D imaging technology for multi-planar image visualisation, diagnosis and treatment planning.

The CBVI data obtained is similar to that from a high-end medical CT scan, but at a lower financial cost to the patient and at a much reduced radiation dose to the patient (Ludlow JB et al, 2006).

Since these devices are becoming widely available in both dental practices and dental imaging centres, reliance upon experience-based guess-estimations is being replaced by accurate imaging technology. As such, treatment outcomes are improved and both patients and dentistry benefit.

Despite these obvious advantages, comprehensive 3D image evaluation associated with CBVI is a new responsibility for dentistry

that must be accomplished in order to comply with the ethics of comprehensive patient care. 

### References

- Almog DM et al (2002) Correlating carotid artery stenosis detected by panoramic radiography with clinical relevant carotid artery stenosis determined by duplex ultrasound. *Oral Surg Oral Med Oral Path Oral Radiol Endod* **94**: 768
- Arai Y, Tammsalo E et al (1999) Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol* **28**: 245-8
- Farman AG, Levato CM, Scarfe WC (2007) A primer on cone beam CT. *Inside Dentistry* **1**: 90-93
- Friedlander AH, Garrett NR, Norman DC (2002) The prevalence of calcified carotid artery atheromas on the panoramic radiographs of patients with type 2 diabetes mellitus. *JADA* **133**: 1516-23
- Hayakawa Y (2007) Newly added oral and maxillofacial radiology imaging technologies. *AADMRT winter newsletter*
- Kumar V, Pass B, et al (2007) Bisphosphonate-related osteonecrosis of the jaws. *JADA* (**138**): 602-609
- Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB (2006) Dosimetry of three CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. *Dentomaxillofac Radiol* **35**: 219-226
- Magliocca KR and Helman JI (2005) Obstructive sleep apnoea: diagnosis, medical management and dental implication. *JADA* **136**: 1121-1129
- Miles DA and Craig RM (1983) The calcified facial artery: a report of its panoramic appearance and incidence. *Oral Surg* **55**(2): 214
- Miles DA (2006) Clinical experience with cone beam volumetric imaging: report of findings in 381 cases. *US Dentistry* **1**(1): 39-41
- Miles DA, Danforth RA (in press) *A clinician's guide to understanding cone beam imaging*, PennWell
- Mozzo P, Proccacci A et al (1998) A new volumetric CT machine for dental imaging based on the cone beam technique: preliminary results. *Eur Radiol* **8**: 1558-64

**For more information on CBCT and volumetric images go to [www.learndigital.net](http://www.learndigital.net).**

## Table 3: Viewing software for clinicians

**SimPlant:** Materialise, Leuven, Belgium

**VIP (Virtual Implant Placement):** Implant Logic, Systems, Cedarhurst, NY, USA

**V Implant, CB Works, Accurex, On Demand 3D:** CyberMed International, Seoul, Korea

**In Vivo:** Anatomage, San Jose, CA, USA

**NobelGuide:** Nobel Biocare, Göteborg, Sweden



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# Clinical Experience with Cone-beam Volumetric Imaging—Report of Findings in 381 Cases

a report by

**Dale A Miles, BA, DDS, MS, FRCD(C)**

*Chief Executive Officer, Digital Radiographic Solutions*



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Until recently, Dr Miles was Associate Dean for Clinical Affairs at the Arizona School of Dentistry and Oral Health. Dr Miles has consulted with many imaging and practice management companies. He earned his Master's degree at the University of Texas, San Antonio. He has a website for teaching dentists and auxiliaries about digital imaging at [www.learnrdigital.net](http://www.learnrdigital.net)

No imaging modality in dentistry has made as great an impact on dental procedures in as short a time as cone-beam volumetric tomography (CBVT), cone-beam volumetric imaging (CBVI), or cone-beam computed tomography (CBCT).<sup>1-7</sup> Three-dimensional image capture and analysis had been absent in dentistry until its introduction in 1998 by Mozzo et al.<sup>1</sup> Now the interest and demand for 3-D imaging studies is accelerating faster than any previous image modality in our profession. The current applications appear to have impacted upon all dentists and dental specialists. This article summarizes the findings of 381 cases referred for CBVI and discusses the current status and future developments for this novel imaging modality. Several interesting cases are included to demonstrate the power of 3-D visualization of pathology.

## Current Applications for CBVT

Table 1 lists the current applications for 2-D/3-D imaging of dental patients. Like Danforth and colleagues,<sup>2</sup> the author uses the term 'volumetric imaging', as in cone-beam volumetric imaging (CBVI), because the image acquisition for the data is unlike conventional medical computed tomography (CT) or multi-detector CT (MDCT). CBVI data is acquired during one 360° video acquisition, using either a flat panel detector or an image intensifier coupled to a solid-state detector or set of detectors like a charge-

**Table 1: Dental Applications for CBVI**

- Assessment of impactions
- Inferior alveolar nerve and sinus floor location
- Pre-surgical implant site assessment
- Paranasal sinus evaluation
- Odontogenic lesion visualization
- Trauma evaluation
- Temporomandibular joint (TMJ) visualization
- Surgical guide fabrication
- Other CAD/CAM devices (3-D models)
- Craniofacial surgery assessment

coupled device (CCD). There are no true gantry-like medical devices and the patient is not moved any distance to acquire a sequential slice (slice thickness). Spatial resolution is expressed in voxels (volume elements) rather than pixels (picture elements), and the volume array can range from 0.1mm to 0.4mm, depending on the machine and size of detector. Detector sizes vary greatly, from arrays as small as 4.0x4.0cm up to 22cm.

In addition, the radiation doses from all CBVI machines are greatly reduced in this image capture, largely because of the low exposure parameters (typically around 70–120kV at 1–3mA). Doses reported are well

1. Mozzo P, Procacci C, Tacconi A, et al., "A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results", *Eur Radiol* (1998);8: pp. 1,558–1,564.
2. Danforth R A, Du I and Mah J, "3-D volume imaging for dentistry: a new dimension", *J Calif Dent Assoc* (2003);31: pp. 817–823.
3. Ludlow J B, Davies-Ludlow L E, Brooks, S L, Howerton B, "Dosimetry of 3 CBCT units for oral and maxillofacial radiology", Abstract accepted for 15th International Congress of the International Association of Dento-Maxillo-Facial Radiology, Cape Town, South Africa, June 2005.
4. Aranyarakhul P, Caruso J, Gantes B, et al., "Bone density assessments of dental implant sites: 2. quantitative cone-beam computerized tomography", *Int J Oral Maxillofac Implants* (2005);20: pp. 416–424.
5. Cervidanes L H, Bailey L J, Tucker G R J R, et al., "Superimposition of 3-D cone-beam CT models of orthognathic surgery patients", *Dentomaxillofac Radiol* (2005);34: pp. 369–75.
6. Nakajima A, Sameshima G T, Arai Y, et al., "Two and three-dimensional orthodontic imaging using limited cone-beam computed tomography", *Angle Orthod* (2005);75: pp. 895–903.
7. Scarfe W C, Farman A G and Sukovic P, "Clinical applications of cone-beam computed tomography in dental practice", *J Can Dent Assoc* (2006);72: pp. 75–80.



**Table 2: Clinical Findings of 381 CBVI reports**

| Site                       | CSP1       | CSP2       | Portl     | ADB        | LVI      | Total Cases<br>n=381 |
|----------------------------|------------|------------|-----------|------------|----------|----------------------|
| No. of Cases               | 253        | 43         | 17        | 66         | 2        | 381                  |
| Airway                     | 13         | 1          | 2         | 1          | 0        | 17+                  |
| Bone                       | 97         | 16         | 10        | 32         | 0        | 155*                 |
| Dental                     | 20         | 3          |           | 3          | 0        | 26                   |
| Sinus                      | 143        | 14         | 12        | 37         | 2        | 208                  |
| TMJ                        | 39         | 10         | 5         | 13         |          | 67                   |
| Vertebral Bodies           | 26         | 1          | 1         | 4          | 0        | 32                   |
| Odontogenic lesion         | 20         | 1          | 1         | 5          | 0        | 27                   |
| Non-odontogenic lesion     | 4          | 0          | 0         | 0          | 0        | 4                    |
| Soft-tissue calcifications | 1          | 1          | 1         | 1          | 0        | 4                    |
| Other                      | 78         | 19         | 3         | 27         | 2        | 129#                 |
| Unremarkable               | 11         | 3          |           | 6          |          | 20                   |
| <b>Total</b>               | <b>452</b> | <b>112</b> | <b>52</b> | <b>185</b> | <b>6</b> | <b>701</b>           |

CSP1 = ClearScan Property in Phoenix, AZ.

CSP2 = ClearScan Property in Peoria, AZ—lab service since closed.

Portl = Portland, OR—lab service since closed.

ADB = Advanced Dental Board, an Internet-based radiology reporting service.

LVI = Las Vegas Institute

TMJ = temporomandibular joint.

"Bone": apical periodontitis, residual cysts, furcations, recent extraction site(s), impacted teeth, idiopathic osteosclerosis.

"Other": includes congenitally missing teeth; calcified, elongated stylohyoid process(es); calcified lymph nodes; retained root(s); metallic fragments; hypoplasias/hyperplasias (facial, teeth); medial sigmoid depression(s); dilacerated roots; tori; enostosis; SSGD (submandibular salivary gland depression); fibrous healing defect; and one possible case of Paget's disease of bone.

Several implants were reported impinging in anatomic spaces.

# includes two pharyngeal masses.

+ includes two cases of blocked ostium.

Non-odontogenic lesions included several antral lesion (extrinsic), a neurolemmoma, and a fractured zygoma.

Vertebral changes included two surgical "repairs".

Two cleft palate cases, one surgical "non-union" case.

Note: gross caries and periodontal bone loss NOT tallied, but reported in the formal interpretive reports.

under 0.1mSv, with several machines as low as 0.007–0.05mSv, whereas MDCT doses range from 0.289–0.723mSv.<sup>2</sup> Others have expressed the dose from CBVI to MDCT in terms of "dose in days per capita background dose".<sup>3</sup> For cone-beam image acquisition, this ranges from 3–48 days, depending upon machine and volume detector size, compared to 103–243 days for maxillary or mandibular imaging performed with MDCT machines. Other differences between CBVI and MDCT are included in the discussion.

## Clinical Studies

For one year, from February 2005 to February 2006, the clinical findings summarized in each of 381 reports were tabulated. The results from imaging centers in Phoenix and Peoria, Arizona, Portland, Oregon, several centers in California, and the Las Vegas Institute, Nevada, appear in Table 2 above. The majority of the cases referred to the services were for pre-surgical implant assessment. An 'analytical report', complete with 1:1 measurements of proposed implant sites, hard copy images, a CD-ROM with images, and a DICOM (Digital Imaging and Communication in Medicine)

viewer, was provided to the referring clinician, usually within 24 hours. An 'interpretive report', from which these clinical findings were summarized, was returned within 48 hours to that same clinician.

## Clinical Case Studies

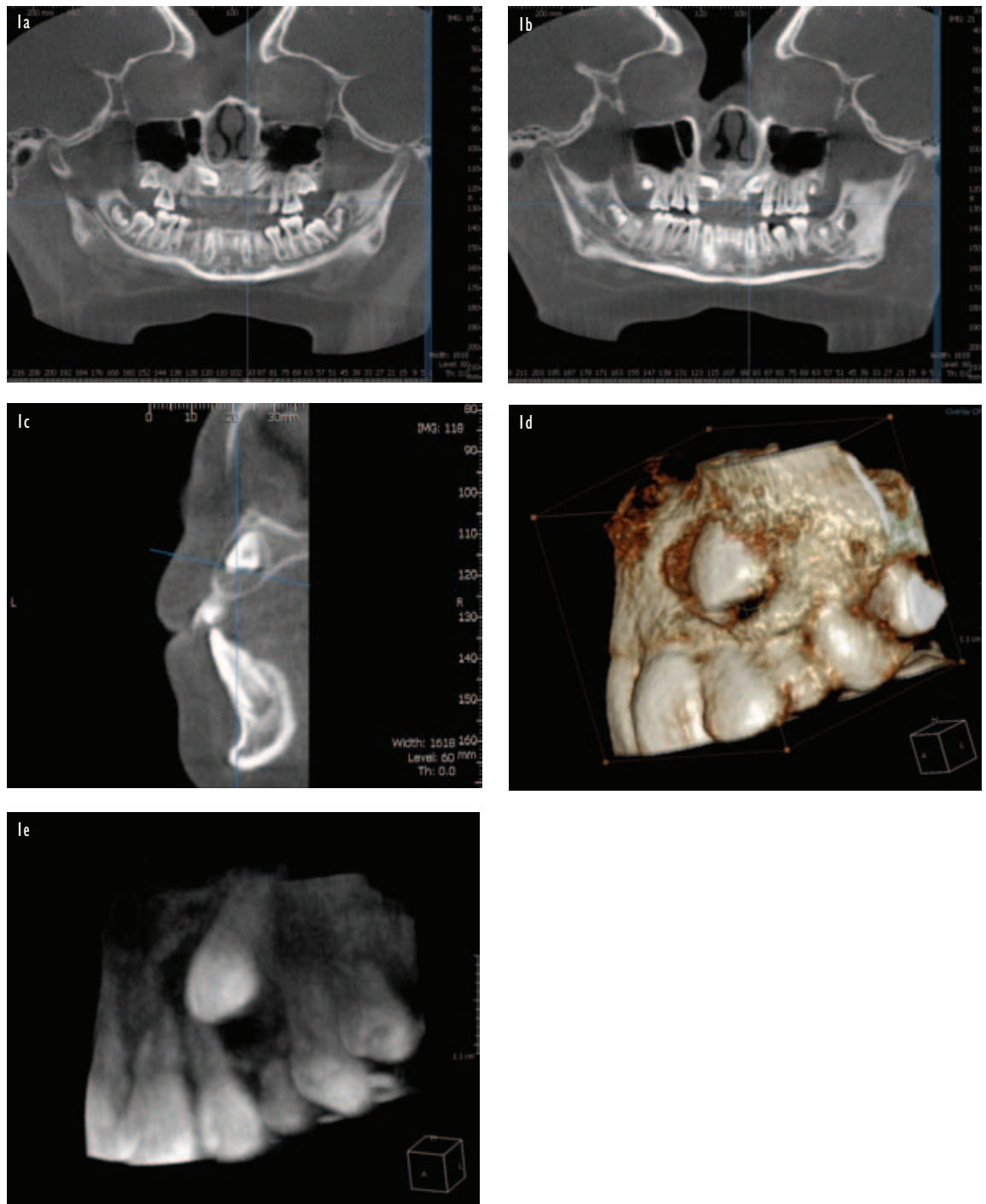
### Case Study 1

A 12-year-old white male was referred to the University of California, San Francisco (UCSF) orthodontic clinic for evaluation of impacted maxillary permanent cuspids. CBVI was performed using a Hitachi CB MercuRay X-ray device. Image reconstruction was performed and the volume data analyzed. Two-dimensional and 3-D images were returned to the referring clinician with a diagnosis of impacted maxillary canines and cystic transformation of the follicle of tooth #6 (see Figure 1).

### Case Study 2

A 35-year-old Asian female was referred to the University of Southern California (USC) orthodontic

**Figure 1: Case Study 1—Impacted Maxillary Permanent Cuspids**

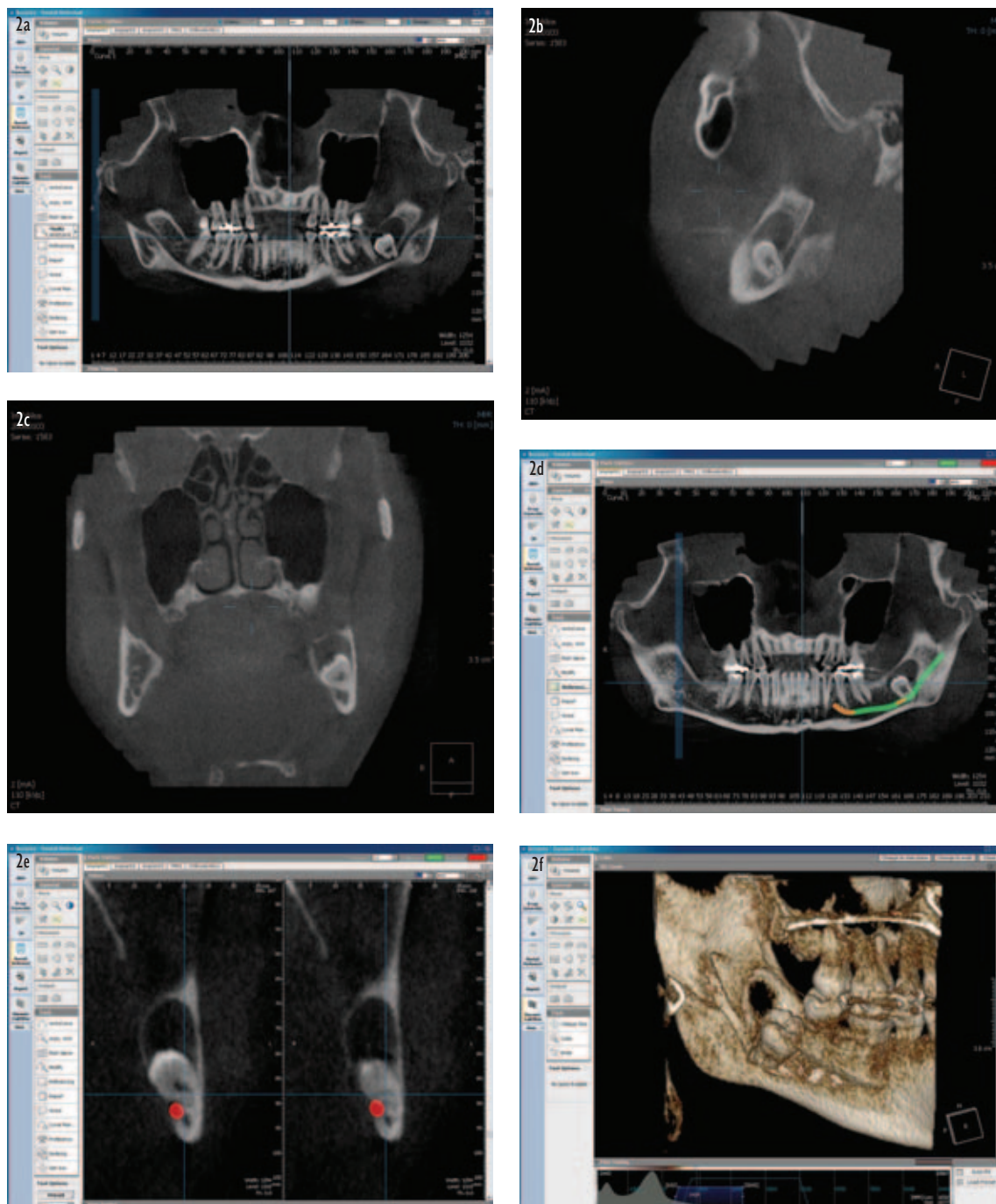


Figures 1a and 1b show thin pseudo-panoramic 1mm slices revealing loss of anatomic shape of the follicle and follicular attachment extension well past the cemento-enamel junction (CEJ), two classic radiographic features of 'cystic transformation of the tooth follicle'. 1c is a sagittal slice showing expansion of the suspected lesion. 1d is a 3-D reconstructed image showing perforation of buccal cortex. 1e is an MIP (maximum intensity profile) image rendered to look 'X-ray like' to show the loss of anatomic shape.

department's Redmond Imaging Center for implant evaluation. A radiographic interpretation report was requested secondary to the implant site evaluation. One of the more significant findings was a large, well-defined pericoronal radiolucency associated with the impacted tooth #17. Images were created using Accurex software (CyberMed International, Seoul,

Korea) which characterized the changes and illustrated the intimate proximity of the inferior alveolar nerve and canal to this impaction (see Figure 2). Significant perforation of the lateral wall of the ascending ramus was noted and a differential diagnosis based on the radiographic appearance was given to the clinician to facilitate lesion management. The differential diagnosis

Figure 2: Case Study 2—Implant Evaluation



Figures 2a and 2d *area* pseudo-panoramic slices revealing the lesion. Figure 2d shows the inferior alveolar nerve/canal track after marking the canal. Figures 2b (sagittal slice) and 2c (coronal slice) show features of size, canal proximity and expansion. Figure 2e is the appearance of the canal in a coronal slicing revealing the canal in red to help visualize the proximity of the anatomic structure to the impaction. Figure 2f is a 3-D reconstruction showing the canal location with respect to the tooth and a cratering effect of the lesion with ramus perforation.

included a) dentigerous cyst, b) odontogenic keratocyst and c) ameloblastoma (doubtful).

### Case Study 3

The patient was referred for a CBCT dental imaging series, which was performed at the Case Western

Reserve University in Cleveland, Ohio. A radiographic interpretive report was generated, which included findings of impacted lower third molars and an occult pericoronal radiolucency about tooth #32. Incidental findings in this case also included a calcified lymph node (Figures 3c, 3d) and chronic inflammatory changes in the patient's right maxillary sinus (Figure 3h).



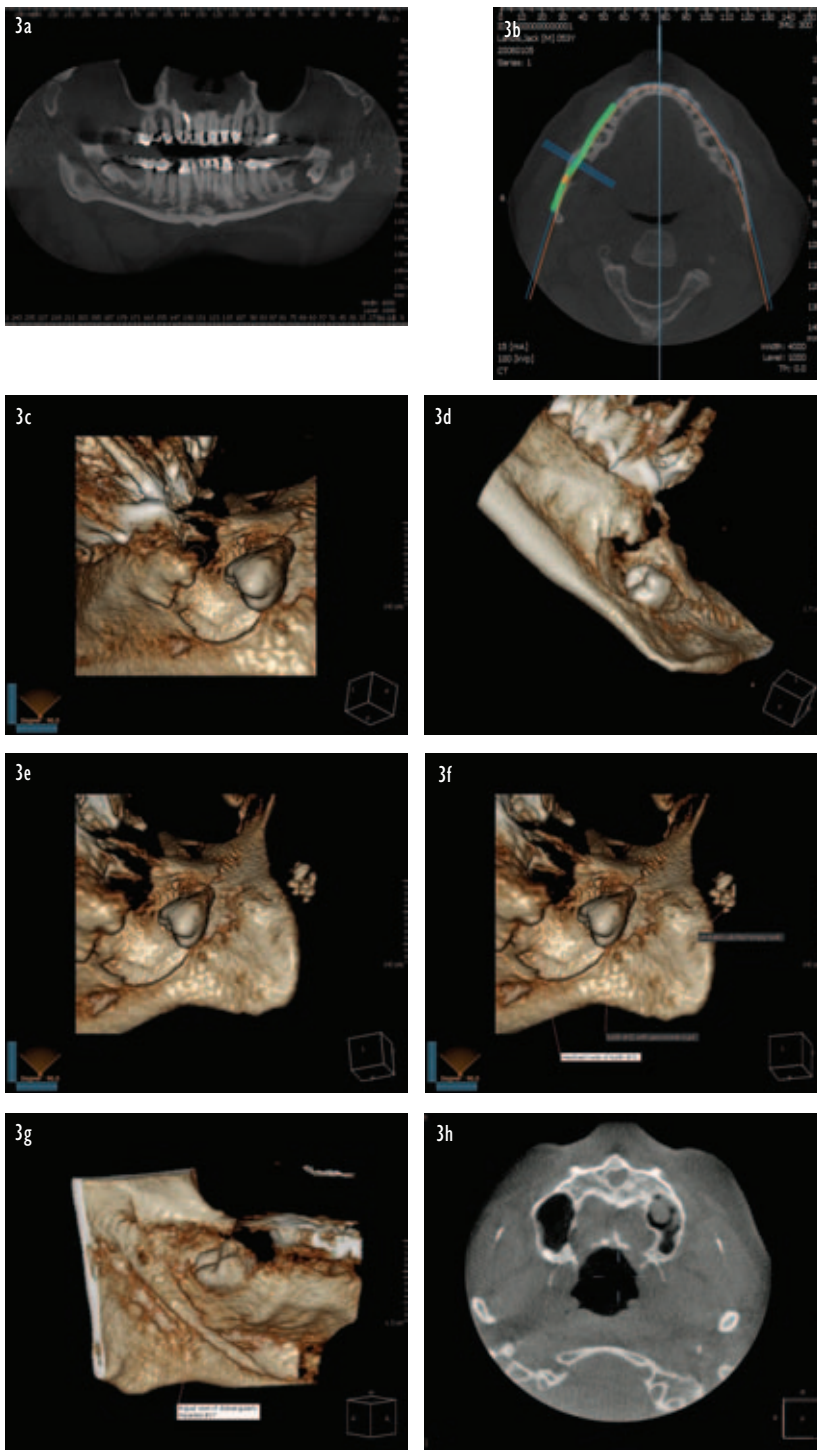
**Figure 3: Case Study 3—CBCT Dental Imaging Series**

Figure 3a shows a large, well-defined pericoronal radiolucency about tooth #32. Figure 3b shows nerve localization and referencing markers to identify slices to view sagittally. Figures 3c and 3d show severe, linear root resorption, suggestive of an odontogenic keratocyst or ameloblastoma. Figure 3d shows occlusal anatomy in remarkable detail. Remember that this tooth is impacted in bone. Figure 3e shows incidental calcification suspected of being a calcified lymph node. 3f shows how these findings can be labeled. Figure 3g is a 3-D reconstruction of the impacted tooth #17. Figure 3h is an axial slice at the level of the mid-palate or top of condylar head, showing left antral change.

## Discussion

There are many differences between MDCT and CBVI. Table 3 cites most of them. The most significant difference, in the author's opinion, is that the image acquisition does not allow separation of soft tissue of the brain; that is, one cannot see gray and white matter. For the dentist and oral radiologist, this is significant, because, although studied, neither practitioner is trained to read neuroanatomy or neural lesions. The cone-beam images acquired are excellent at displaying bony anatomy and skull spaces, but soft tissues are only seen in the cervical and external surfaces (see Figure 1). CBVI scans evaluated for the referring dentist or dental specialist by the oral and maxillofacial radiologist are of the airway, paranasal sinuses and nasal cavity, temporomandibular joints structures, osseous structure, and dental structures. Our clinical studies demonstrated almost two 'reportable findings' per scan, many of which led to referrals to other dental specialists, rheumatologists and otolaryngologists. In addition, because of the unique 3-D and slice rendering, even periapical lesions, missed during conventional intra-oral and panoramic examination, were found on CBVI images and recommended for treatment and follow-up. Table 4 lists currently available CBVI machines.

## Future Developments

Several other manufacturers are planning to introduce cone-beam imaging devices to the dental market in North America in the next year. Among these are Sirona (Bensheim, Germany), and Planmeca (Helsinki, Finland), two companies in the process of finishing development of a CBCT device.

Planmeca's CBCT machine, the ProMax 3D, is unique in the industry because it consists of an upgrade of its existing ProMax digital panoramic machine. This means that existing ProMax owners will have a substantially less expensive upgrade path to 3-D imaging capability. Planmeca is the only company to plan a device based on an existing dental X-ray machine.

Sirona's CBCT device is called Galileos. Sirona will offer a 3-D imaging software program called Galaxis 3D with their device.

There is no doubt that cone-beam volumetric imaging will change the way dentists approach many procedures. Three-dimensional data appear superior for visualization of anatomy and many aspects of pre-surgical implant and orthognathic surgery, as well as orthodontic planning. Even specialties like endodontics are looking to CBVI to assist decision-making in complex or failed cases. With the excellent hardware

devices listed here, and in progress, and the amazing software tools now available to clinicians, patient management will improve, surgical risk will be reduced, and complex dental procedures such as implant surgery will be vastly simplified. All of these developments and tools will ultimately improve patient dental care, the major goal of all of our profession. ■

**Table 3: CBVI Versus MDCT**

| <i>Parameter</i>                   | <i>CBVI</i>                     | <i>MDCT</i>                         |
|------------------------------------|---------------------------------|-------------------------------------|
| <i>Image acquisition speed</i>     | <i>Fastest (10—20s)*</i>        | <i>Slow—several minutes</i>         |
| <i>Absorbed X-ray dose least</i>   | <i>(Average .025mSv)*</i>       | <i>High (average about .500mSv)</i> |
| <i>Hardware expense</i>            | <i>Moderate (\$180K)*</i>       | <i>High (approx. \$1M)</i>          |
| <i>Cost of dental examination</i>  | <i>Inexpensive (&lt;\$400)*</i> | <i>Expensive (\$700—1500)</i>       |
| <i>Dentally specific software</i>  | <i>Yes, readily available*</i>  | <i>Limited</i>                      |
| <i>Dental 'reporting' software</i> | <i>Yes*</i>                     | <i>None</i>                         |
| <i>Convenience</i>                 | <i>Very convenient (day)*</i>   | <i>May require evening appt.</i>    |

CBVI = cone-beam volumetric imaging, MDCT = multi-detector computed tomography.

\* advantage cone-beam volumetric imaging

**Table 4: Companies Currently Providing Cone-beam CT (CBCT) Systems**

Aperio Services: NewTom 3G  
 J Morita: Accuitomo  
 Hitachi Medical Systems: CB MercuRay  
 Imaging Sciences: i-CAT  
 Imtec: Iluma





by Dale A. Miles, DDS, MS, FRCD (C)

# Cone Beam 3D— Is It Really for Me?

## Introduction

Making clinical decisions with 2D grayscale images is hard. Humans and human structures are not flat; patients are three dimensional. How do we expect to know the truth about the extent of a disease process, or a tooth position and its relation to important anatomic structures, when we're actually guessing at the extent of disease from flat, grayscale images?

Unfortunately, many dentists did not master the intricacies of interpreting X-ray films, phosphor plates, digital images— intraoral or panoramic—even before the advent of cone beam 3D imaging and visualization in 3D color. Do you remember struggling with Clark's rule, tube shift principles, the buccal object rule or the SLOB rule, just to figure out if a mesiodens was on the palatal or the facial?

By the way, the SLOB rule stands for “same on lingual opposite on buccal” and is the simplest way to localize objects on X-rays. It took us 25 years of teaching to figure that one out!

So along comes CBCT (cone beam computed tomography) which, although simple to perform, is quite complex to understand and master<sup>1</sup>. And it isn't even computed tomography. The acquisition of the image occurs with one pass around the patient, unlike conventional medical CT which moves the patient lying on a gantry into a scanner at 1mm up to 1cm increments with very high X-ray dose to the patient. Conventional CT detects every “point” in the scan. CBCT detects (captures) only very small cubes, called voxels. This is a partial explanation for why we do *not* get true Hounsfield units in CB 3D/CBCT imaging.

The dose from a conventional medical CT head scan has been calculated at 2,100 microsieverts ( $\mu$ Sv). The dose from a typical 8cm x 8cm FOV (field of view) Cone Beam 3D scan subjects the patient to only about 17 to 360 microsieverts.<sup>2</sup>

And unlike conventional medical CT, cone beam 3D imaging is dentally specific. It was made for us! And by the way, we receive 3,600 microsieverts annually just walking around the planet exposed to things like radon, cosmic rays and consumer products. Cone beam 3D imaging, used prudently, is the least of our worries—from the radiation exposure point of view.

So you have to ask yourself the very question posed in the headline of this article: “Is cone beam 3D imaging really for me?” I assure you the answer is a rhetorical and resounding *yes!*

## How do you decide?

If you answer *yes* to any or all following questions, cone beam 3D imaging will be invaluable to you.

1. Do you do root canals?
2. Do you perform extractions?
3. Have you struggled with locating the position of the tooth that is impacted?
4. Have you ever had to rule out sinus problems mimicking a toothache?
5. Have you ever had questions about the appearance of a condyle on a panoramic image?
6. Are you planning to place implants surgically?
7. Are you planning to learn about obstructive sleep apnea and how dentists can play an important role and possibly save lives?
8. Have you ever had to take a panoramic to try to determine if a fracture was present in either the maxilla or the mandible?
9. Have you ever struggled to determine whether there was any residual periapical disease present following root-canal therapy by looking at your 2D grayscale images?
10. Do you have to spend \$75,000-\$200,000 to own a machine just to find out if there's a residual periapical lesion on a toothache treated endodontically?

Fooled you! The answer to the last question is actually *no*! You don't have to own a cone beam machine to use the data acquired in the scan. Almost every machine manufacturer provides a "viewing software program" with the machine software so that you can order a cone beam 3D scan and then look at the data burned onto a CD that is sent to you along with the individual data files (DICOM files or .dcm). DICOM stands for digital imaging and communication in medicine—the standard protocol for distributing and sharing patient imaging data.

There are often tools within the software you receive on the CD to do simple tasks such as viewing and measurement. You can also purchase third-party independent software for doing tasks such as implant site assessment and planning, surgical guide construction and the like. In fact, all the images in this article were made using a third-party software called OnDemand3D (Cybermed, Seoul, Korea and Irvine, California).

So really there is no excuse for you to not use cone beam 3D imaging. However, like any other disruptive technology, the manufacturers sell the machine in the marketplace long before the education about the technology can catch up. You and I both know there's a lot of technology sitting on our shelves which looked exciting at the time of purchase, but after being used a few times, is sometimes relegated to gathering dust. This should not happen with cone beam 3D imaging.

The following are visual examples of cases in which the images obtained by cone beam 3D imaging made the clinical decision simple. There are also cases where unexpected pathology, called occult pathology, was discovered and an important medical referral was made because of the finding's significance. Enjoy the images. It is my bet that you'll soon be using cone beam 3D imaging or will soon purchase a dental cone beam machine to make your dental practice life a whole lot easier and more precise.

## Case Presentation

### Case 1

A 54-year-old white female was imaged for potential implants in the left posterior mandible. The patient had no chief complaint.



Reconstructed cone beam 3D panoramic image at 25mm. There does not appear to be a lesion on tooth #30. There is a large residual lesion of endodontic origin on tooth #12.

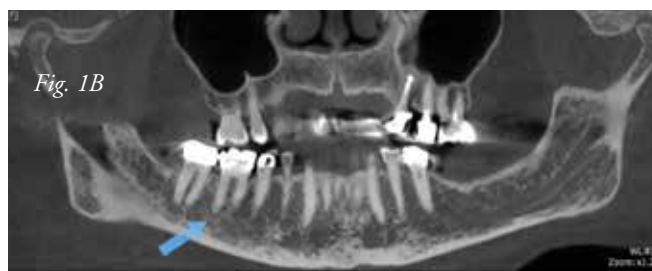


Fig. 1B. In a "thin slice" reconstructed panoramic, the lesion on the distal root of tooth #30 is now visible.



Fig. 1C. A thin slice coronal image verifies the lesion. This lesion would not have been seen on a conventional panoramic or periapical image (film or digital).

### Case 2

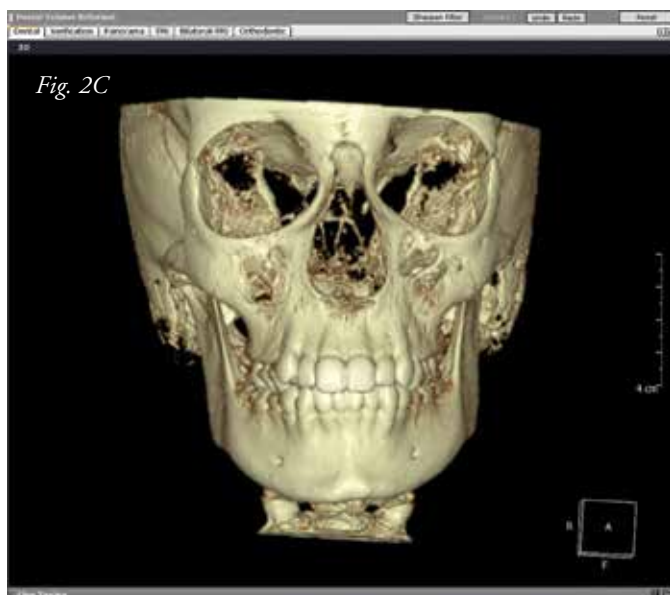
An 11-year-old white female was imaged using cone beam 3D when extra teeth were found on a routine panoramic image.



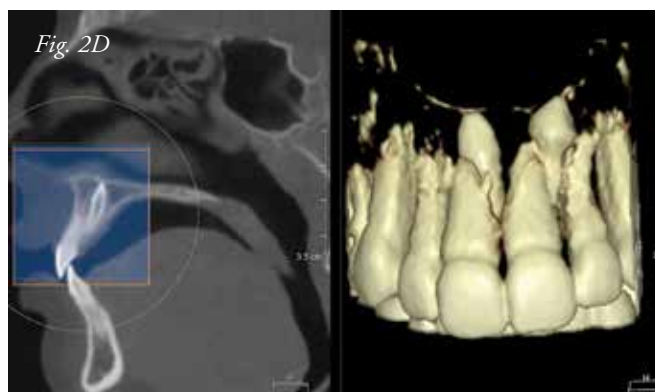
Simulated panoramic shows a ball-shaped "lesion" between the apices of teeth #28 and #29, three of the four third molar follicles, and, if you look closely, blurred tooth-like structures near the apices of the central incisors. The next few images (2B-2D), obtained from the cone beam 3D data, show the power of seeing these hidden structures and localizing them precisely.



A reconstructed MIP (maximum intensity profile) image is used in the cone beam software to delineate the tooth and bone structures. Note the presence of not one but two supernumerary mesiodens in the anterior maxilla, as was suspected by the clinician. MIP images are also great for visualizing calcifications such as carotid plaques, tonsilloliths and physiologic calcifications within the cranial base.



A 3D reconstructed view of the entire head was made demonstrating that the mesiodens are not located on the buccal or facial aspect of the arch.



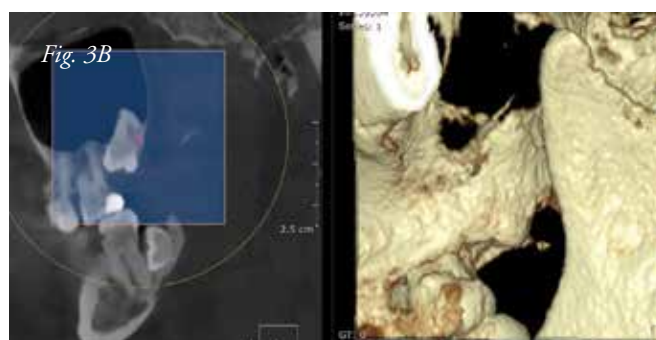
Using a simple tool called a "cube" tool, one of the mesiodens was located on the sagittal image on the left. The cube tool dragged out so the circle included the anterior region bilaterally exposing not one but two supernumerary mesiodens. The software that made these images was OnDemand 3D by CyberMed. (Irvine, California and Seoul, Korea).

### Case 3

A 37-year-old female was referred for cone beam imaging because of third molar impactions seen on the panoramic image. No wonder previous dentists she had seen elected to leave her impacted teeth alone. The figures below of impacted tooth #16 illustrate just one of the impaction problems.



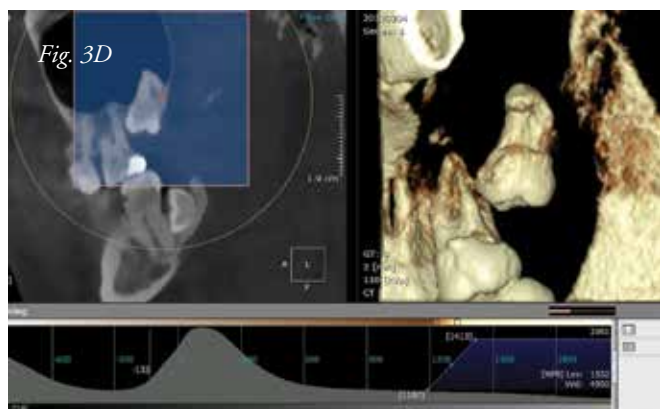
A thin slice (0.1mm) 2D grayscale sagittal image of tooth #16 suggesting a root problem.



3D color reconstruction of the area to show the overlying bone.

1/4 pg





Using image processing in the OnDemand 3D software we can "strip away" the overlying bone to show the dilacerated root.



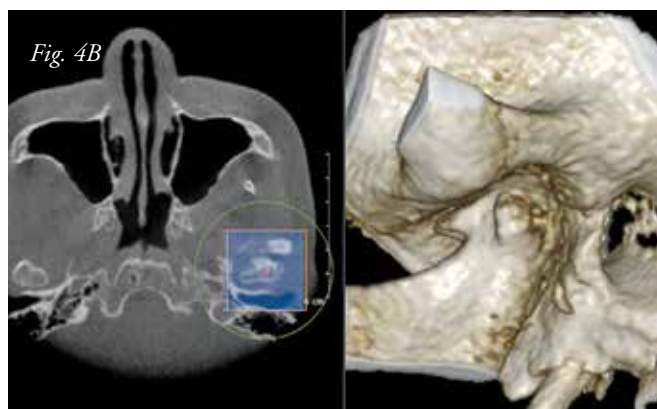
The full extent of the dilacerated root structure is not appreciated until we see a 3D color reconstruction in the coronal plane. We are viewing the tooth from the posterior in this image. This extraction would not be simple!

#### Case 4

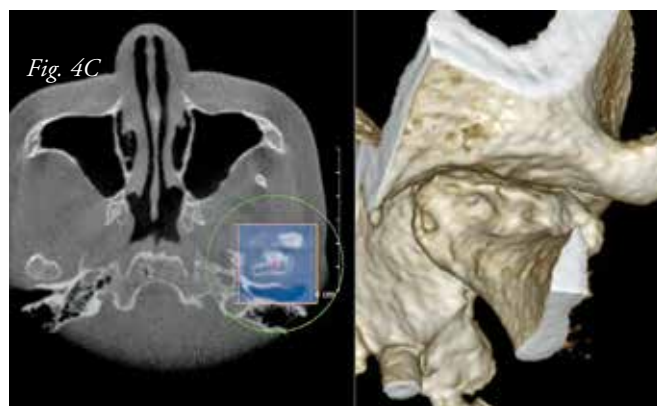
A 58-year-old Japanese woman said she had pain. Her dentist examined further and was able to see her TMJ complexes.



There appears to be a small osteophyte or "bird beak" on the anterior portion of the left TMJ condyle.



3D color reconstruction of the left condylar head verifies the suspected "bird beak." However the term "bird beak" is a holdover from the days of simple planar tomography in which cuts of approximately 3mm were taken of the condylar head. Cone beam 3D imaging is now able to clarify the true nature of the osteoarthritic change. This is seen in Figure 4C.



3D color reconstruction of the left condylar head shows the full extent of the change on the anterior surface of the condylar head. This change, also seen in other loader joints such as the knee, is termed "lipping."

#### Case 5

This 28-year-old male patient was assessed using cone beam 3D imaging because of his snoring and sleep apnea problems.

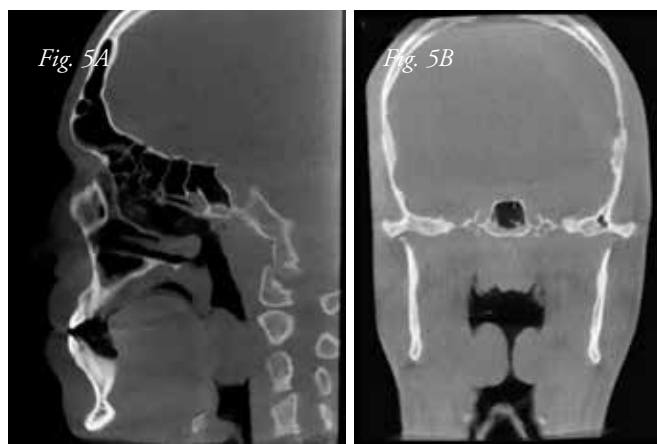
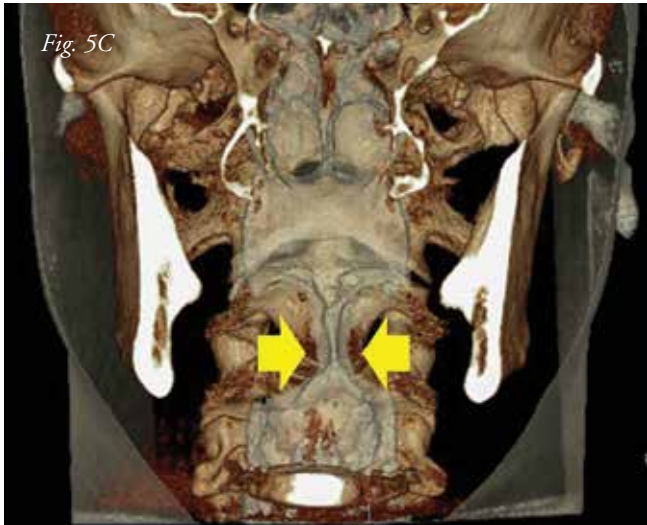
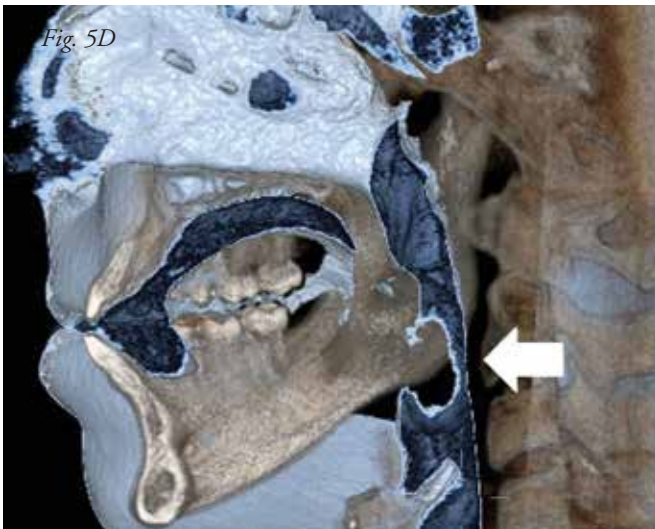


Figure 5A- A 2D grayscale sagittal view just to one side of the midline showing and airway mass. Figure 5B - A reconstructed coronal image in thin slice showing grossly enlarged tonsils.





A color 3D coronal image reconstructed at approximately 20mm showing the narrowing of the airway from the tonsillar tissues (yellow arrows).



A color 3D sagittal image, reconstructed at approximately 20mm, showing the narrowing of the airway (white arrow). The airway itself can be measured linearly or volumetrically in the OnDemand 3D software.

*I am still amazed at the power of the image processing which can be performed on the individual grayscale cone beam 3D image data set.*

## Conclusion

These are just a few of the more than 17,000 cases which I have seen and reported in the past six years. I am still amazed at the power of the image processing which can be performed on the individual grayscale cone beam 3D image data set. The images from the examples above would have been embedded in the reports for complete characterization of the problem(s) for which the referring dentist has responsibility. The report and the images truly help to make the clinical decision-making much easier for the dentist. If you adopt cone beam 3D imaging, that dentist could be you. ■

## References

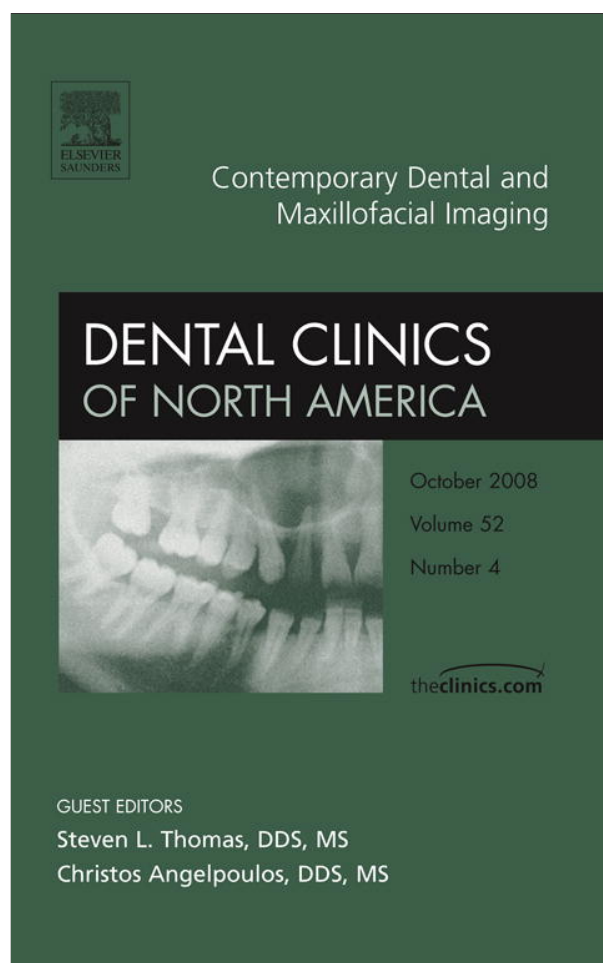
1. Miles DA: *Color Atlas of Cone Beam CT for Dental Applications* (title change), Quintessence Publishing Company, Inc., Hanover Park, IL, (2nd edition, December 2012).
2. Rottke D, Patzelt S, Poxleitner P and Schulze D: Effective dose span of ten different cone beam CT devices. *DMFR* (2013) 42(7).

Questions about cone beam? Ask them at [Dentaltown.com/magazine.aspx](http://Dentaltown.com/magazine.aspx).

## Author Bio



**Dr. Dale Miles**, a diplomate of the American Board of Oral and Maxillofacial Radiology, has authored more than 130 peer-reviewed articles and six textbooks, including the best-selling cone beam textbook, *Cone Beam CT, Color Atlas of Cone Beam CT for Dental Applications* (Quintessence Publishing). He has a website for teaching dentists and staff about digital and cone beam imaging at [Learndigital.net](http://Learndigital.net) and a social network television channel called [Interactiveimagingtv.com](http://Interactiveimagingtv.com). Dr. Miles is in full-time practice of oral and maxillofacial radiology in Fountain Hills, Arizona, and is president of EasyRiter, LLC, which produces a simple CBCT report-generating software for the profession.



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## The Future of Dental and Maxillofacial Imaging

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This issue of *Dental Clinics of North America* has covered old and new imaging modalities, their current applications, and some more contemporary applications such as image-guided surgery. What is left to be said?

I will start first with what dentists and oral and maxillofacial radiologists will most likely not do, even with our newest imaging technique—cone beam volumetric tomography (CBVT).

Although at least one manufacturer has previously shown vessels in the head and neck region in their CBVT machine brochure, dentists and oral radiologists will probably never do contrast procedures. Blood is not stationary, and to see the flow patterns, contrast nonionic agents such as Omnipaque (GE Healthcare, Piscataway, New Jersey) are used. Many of us have used these agents for sialography in the past, but this salivary gland investigative technique is labor intensive and has largely been replaced by conventional CT with contrast and MRI for salivary gland evaluation.

We are neither trained to perform these interventions, nor do we require any application for evaluation of head and neck problems with which we deal. Cerebral angiography is used to detect aneurysms, clots that have made their way to the brain giving rise to stroke and other vascular problems. The catheter is inserted into the femoral or carotid artery, and the injected contrast medium administered. The procedure takes hours to perform and must be done in a hospital setting by an interventional radiologist. We will never be trained or licensed to do these procedures. We cannot image vessels in the head and neck region with cone beam technology.

Another “head and neck” radiology task we will never perform is the interpretation of neurologic structures in the brain—at least with CBVT. The exposure factors and the image acquisition technique do not allow us

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to visualize “gray and white” matter of the brain. In fact, we wouldn’t want it to. Again, although many oral and maxillofacial radiologists are “familiar” with the features of disorders and disease affecting the brain such as multiple sclerosis and disseminated herpetic lesions, we are neither trained nor licensed to perform interpretation of these neural structures and problems. And, luckily for us, CBVT cannot image these types of problems. The CBVT machines and techniques are suitable for bone and some soft tissue imaging tasks we require but are vastly inferior to conventional CT for most medical problems.

Finally, it is my opinion that dentists and dental specialists will never completely replace some conventional imaging techniques such as intraoral and panoramic with CBVT.

These restrictions aside, CBVT has opened a new door for all of us in the dental profession. We can now perform limited imaging tasks, like our medical radiology colleagues, with software tools that rival theirs for visualization of anatomy and pathology specifically related to our desired applications. Let’s now see what the “future” might hold for us with all of the imaging techniques available. What follows is a series of questions we’ve been asked or ask ourselves, followed by my “predictions” of how and why oral and maxillofacial imaging techniques will evolve.

### **Predictions for intraoral, panoramic, and “advanced” imaging modalities**

#### ***Question #1: Will intraoral and panoramic imaging disappear or be replaced by CBVT?***

My response is a resounding, “NO!” Certainly the ability to “slice” through a patient’s dental anatomy at 0.15 mm thicknesses could uncover a carious lesion, right? The answer is “Yes” and “No.” Although we can see cavitations in some volumes more precisely (Fig. 1), in others the scatter artifact, running horizontally through the occlusal region, will obscure many lesions (Fig. 2). Besides, it is currently, and I think for many years to come, unjustified to use CBVT for caries detection [1,2]. Why you might ask?

First, as low as the x-ray doses are for CBVT machines, the x-ray dose is still too high for many dental imaging tasks. Second, the simpler, more conventional techniques to image interproximal cavities still have the highest resolution. In addition, certain panoramic machines can now provide high-resolution interproximal images, collimated to reduce dose and provide periapical information that may reduce the total number of intraoral images we require for treatment planning (Fig. 3). The large bitewing images below also could replace some posterior intraoral images from the cuspid posteriorly. Note how they even give a detailed view of the third molar region. This would leave only a few anterior views in an initial new patient examination. And, those are the images the auxiliary likes to do!

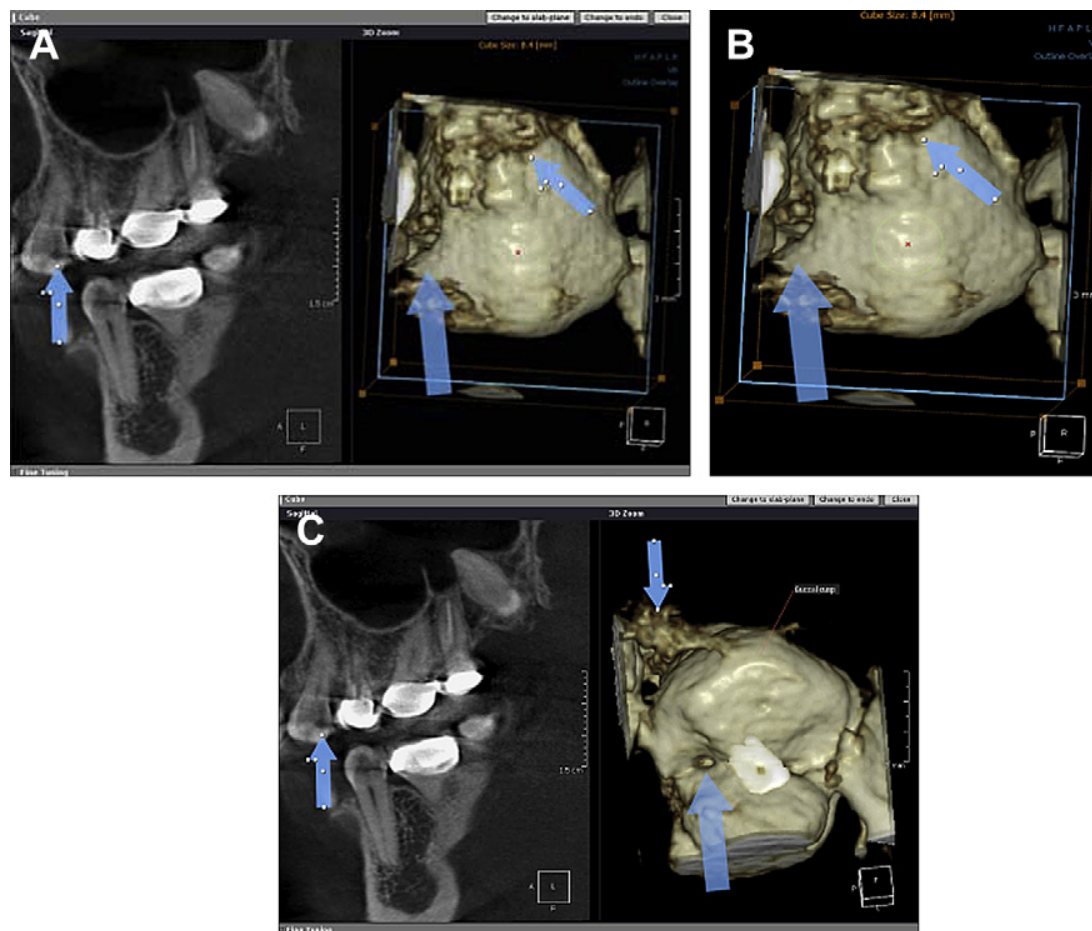


Fig. 1. (A) Interproximal carious lesion on the distal of tooth #12. There is some distortion of this area because of scatter artifact from the restorations. The 3D color reconstructions using N-Liten from PlanmecaUSA (Roselle, Illinois). The “Cube Tool” allows better visualization of the lesion in (B) (large blue arrows). However, the noise artifact created by these restorations is apparent (small blue arrows) in 3D views. (C) The lesion, although appearing “interproximal” may actually have developed as a “distal pit” lesion as seen in the 3D color view (large blue arrow). Noise is again distracting (small blue arrow). Case images in Planmeca N-Liten software.

### Prediction #1

*Although we may use fewer intraoral images, both bitewing and periapical, and even with advances in panoramic techniques and software that can replace some intraoral images, we still will need the higher resolution capability of film or digital intraoral images for high-risk “caries patients” to see the earliest lesions. Cone beam imaging will not replace intraoral or panoramic.*

### Question #2: Will tomography or panoramic imaging technique be replaced by CBVT?

My response to this question is a hearty “Yes”! Although tomography was considered “state-of-the-art” for implant planning, even with the best machines and tomographic programs that are available in some panoramic machines, the technique is “labor intensive” once again. Despite the acceptable quality that these images may have, they cannot be made thin enough to precisely locate the alveolar crest in many cases. The technique’s

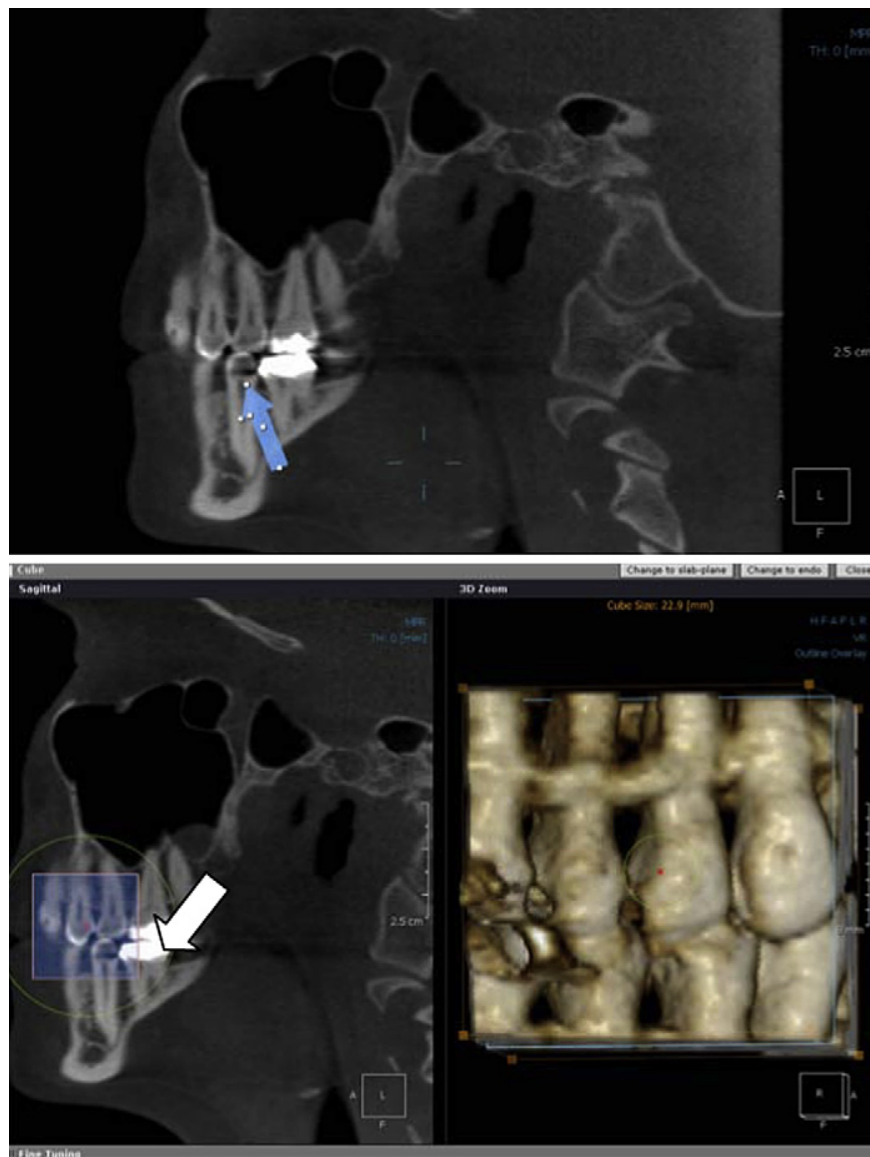


Fig. 2. This volume from an Imaging Sciences i-CAT also shows how even minor scatter artifact from restorations can obscure caries detection. Volume was imaged in OnDemand3D, (CyberMed International, Seoul, Korea).

magnification factors with either dedicated tomography or panoramic tomography programs must always be considered. Clinicians still have to factor in these technique parameters and leave the traditional 2 mm of “safety margin.” With CBVT the measurements are accurate to within 1/10 mm in most software. And, all structures are rendered in a 1:1 ratio in the image reconstruction software. The margin of error is more precise with CBVT. You can “recapture” 1 to 1.5 mm of space that might mean the difference between being able to place a fixture and not being able.

As an aside, many clinicians first encountering CBVT images, and stuck in their conventional imaging techniques, confuse the term 1:1 ratio with their perception of “life size!” If the structures are rendered in a precise 1:1 ratio, we can make the image of an implant site into an 8- × 11-inch glossy print. And if the measured length says 12.2 mm, it IS 12.2 mm to

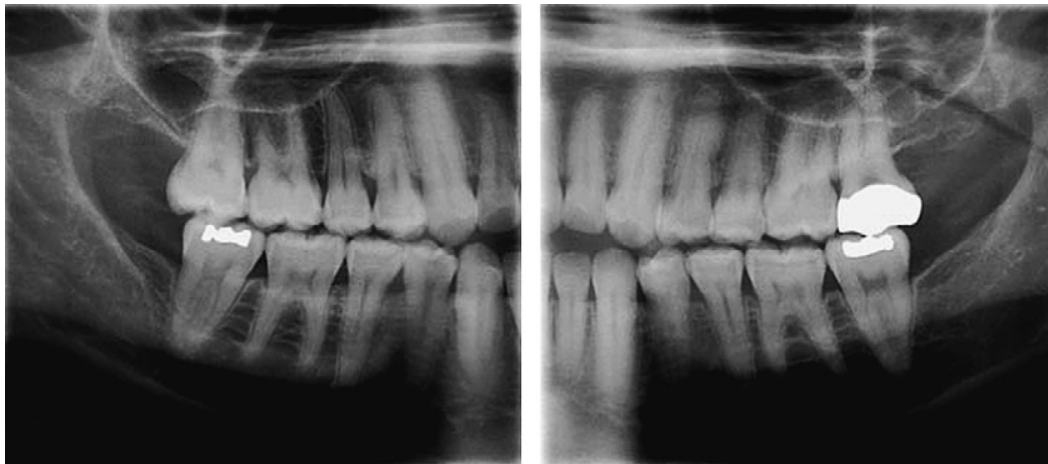


Fig. 3. A bitewing image from a panoramic image capture. Almost all contacts are “open” making caries detection in the bicuspid region possible. This can only be accomplished because of a C-arm on the top of the ProMax (PlanmecaUSA, Roselle, Illinois) panoramic machine, which allows the device to start from a different location and “open” the bicuspid contacts. Currently, in all other panoramic machines these contacts are overlapped and cannot be used for detecting carious lesions interproximally.

within 1/10 of a millimeter! You do not have to use tiny little transparency overlays with implant icon fixtures over a tiny little image of the mandible or maxilla. Those days are gone! That is not the “state-of-the-art” any longer. Images like that in Fig. 4 illustrate this point.

As for panoramic imaging remaining a “standard of care,” I can state this. In my opinion it really was never a standard of care. Clinicians, including oral and maxillofacial surgeons, were placing themselves at some risk for using a panoramic image as the sole radiographic means of implant site assessment. Some still do. Now that CBVT has become so widely available, the use of a panoramic image, with the myriad of positioning errors made and the lack of the cross-sectional information cannot be justified. Anyone who persists using this image as their only image for implant site

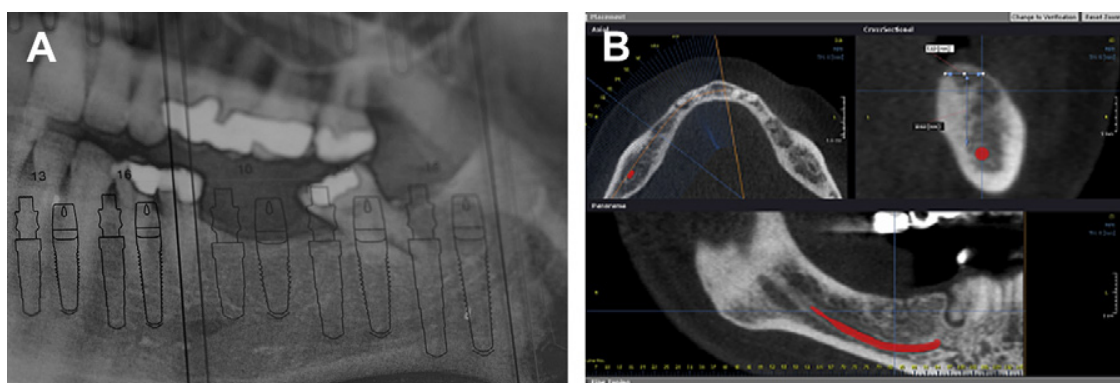


Fig. 4. (A) A panoramic image with a “transparency overlay” of generic implant icons. (Courtesy of Ronald Shelley, DMD, Glendale, AZ). (B) A typical cross-sectional display with nerve marked in red and precise measurements labeled on the proposed implant site for tooth #30 (implant image #83). If needed, an icon can be overlaid to better visualize the proposed site.



evaluation will have a serious liability issue in my opinion. Fig. 5A–D show the improved information available with CBVT technique software.

**Prediction #2**

*CBVT will replace conventional tomography as the “standard of care,” and should now be used in place of panoramic imaging to assess any implant site.*

**Question #3: Will CBVT replace conventional CT as the “state-of-the-art” or the “standard of care” for presurgical implant site evaluation?**

Yes. Period! With the substantially reduced patient x-ray dose [3], the “implant-specific” software, the smaller voxel size, the wider “availability” and the reduced cost, CBVT will become the standard of care within the foreseeable future. This is obvious from the images seen above.

**Prediction #3**

*CBVT will replace conventional CT as the standard of care for implant assessment.*

**Question #4: Will the “cephalometric” image reconstructed from a CBVT data volume replace the conventional cephalometric image for cephalometric analysis?**

My answer today is “not yet.” Since the 1940s when the cephalometric techniques were introduced, orthodontists have developed many ways of

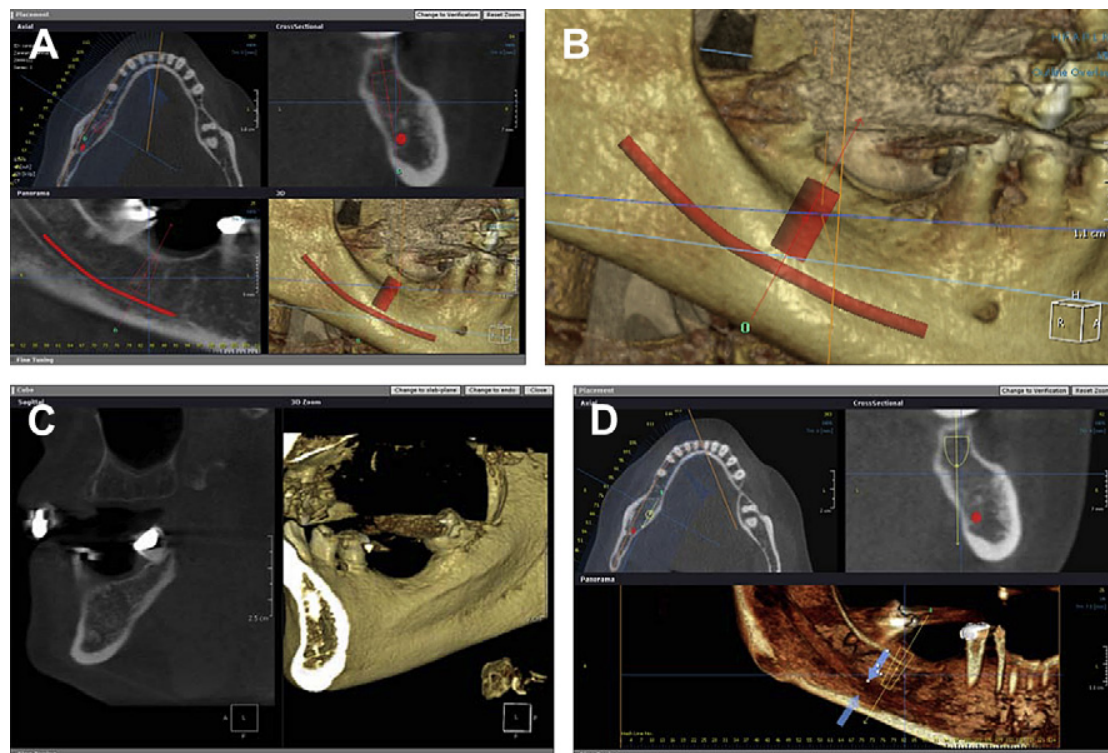


Fig. 5. (A) Typical implant planning image set shows a “generic” implant fixture orientation in relation to the inferior alveolar nerve. (B) A close-up image of the case above isolating the 3D color volume and proposed implant placement visualization. (C) A 3D colored view to show the submandibular fossa in relation to the implant site. (D) A colorized “slab” rendering allows the clinician to actually see the canal and the desired position of the intended implant fixture. Precise measurements can now be made.

performing an “analysis” of the conventional cephalometric image to predict final tooth position and have been using these “analyses” for more than 60 years. Today, in the dental profession, just because a technology is available in the marketplace does not mean it can immediately replace the current “standard.” This was obvious from the discussion above. However, in orthodontics, this is especially true. As dentistry’s first specialty, orthodontics has had a long history of examining and developing the “clinical science” behind their orthodontic analyses. In my opinion, here’s what will and should happen before CBVT completely replaces conventional cephalometric techniques.

With the push in dentistry for evidence-based dentistry, multipatient, multitrail research will need to be completed. Possibly 50 patients at each of 10 dental schools or other sites will need to have their traditional cephalometric analyses performed on conventional “cephs” compared with a matching number of patients at each site whose cephalometric image(s) are reconstructed by CBVT software. Then these patients will need to be followed up for 5 years to see if the CBVT technique is more precise than the conventional technique for predicting final tooth position. My gut feeling is that CBVT will outperform conventional cephalometric measurement. Why? The main reason is the fact that, the image data, as stated earlier, is reconstructed at a precise 1:1 ratio. As a result, the magnification artifact(s) inherent in conventional cephalometric x-ray techniques are eliminated. Thus, the localization of the typical landmarks used in the analyses will be more precise, reduced operator error. So, the adoption of CBVT for orthodontic cephalometric analyses is inevitable. Software manufacturers are just now beginning to create the software to perform these analyses. I do not believe orthodontists are ready to “give up” their traditional analyses just yet.

#### ***Prediction #4***

***CBVT will replace conventional cephalometric x-ray technique as the standard of care within 7 to 10 years after the “science” has been completed.***

#### ***Question #5: Will CBVT imaging replace panoramic imaging for third molar extraction?***

In my opinion, my answer would be “not completely.” Not every impacted third molar is located close to anatomic entities that could cause problems like the inferior alveolar nerve (IAN) or the maxillary antra. Some are; some are not (Fig. 6). If an oral and maxillofacial surgeon can obtain the initial information on a panoramic image, film, or digital image, and if the teeth to be removed are in locations that do not approximate the sinuses or IANs, then the clinical treatment decision is simple, the panoramic image provides the necessary data by itself, and CBVT may not be required. They may not even require a “large-volume” machine. If the machine is capable of capturing both the panoramic image alone (low dose to patient) and CBVT data (higher dose to patient), then the decision making

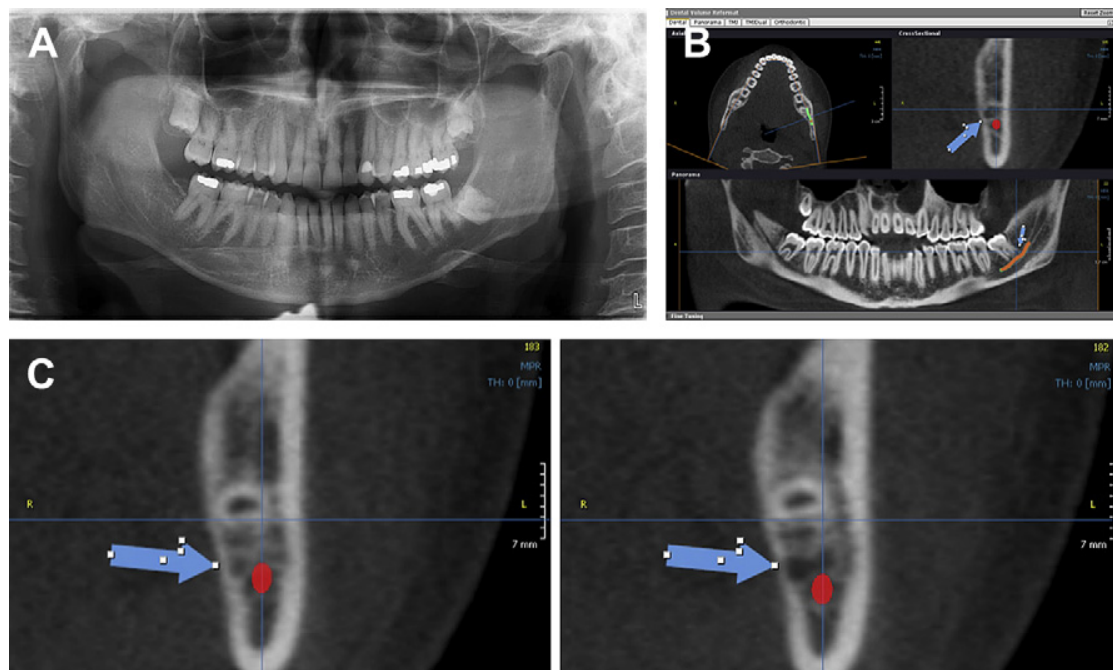


Fig. 6. (A) This excellent digital panoramic reveals 3 impacted molars. If only the upper molars were impacted, a CBVT volume may not be necessary. However, the lower left third molar does appear to be in close proximity to the IAN, so a CBVT should be ordered. Some machines like the ProMax3D can do both using CBVT volume only when needed. (B) This “pseudopanoramic” from an i-CAT volume has the nerve colorized and shows the developing apex of tooth #17 touching the IAN. (C) These cross-sectional images of tooth #17 show the proximity of the IAN to additional root areas of the tooth touching the IAN.

is improved as well as the productivity. In an oral and maxillofacial surgeon's office, time is money, and surgical removal of third molars is the primary procedure. Many oral and maxillofacial surgeons do not want to wait for image reconstruction from CBVT machines (as quick as they may have become) to see a panoramic view in a simple case.

#### **Prediction #5**

***CBVT will replace conventional panoramic images as the standard of care only for difficult third molar extraction cases.***

### **Future considerations for cone beam volumetric tomography imaging**

This is perhaps the most difficult area to make any predictions about because of the ingenuity and creativity of the dental software companies. New, innovative software technology is introduced constantly to our profession. Dentists are more and more computer literate and find processes and tasks in their own offices they wish to simplify or streamline.

Here are the primary areas for growth and thus predictions for dental imaging in the future. Most future uses, obviously, are related to CBVT.

- Software improvement
- Image-to-device processes

- Picture archiving and communication systems (PACS)/ radiographic information systems (RIS)

### Software improvement(s)

Software from the machine manufacturers is already good. They could not have introduced their hardware without accompanying software and be successful. However, some of the manufacturers have proprietary software. Examples are Imaging Sciences International (i-CAT, Hatfield, Pennsylvania) and AFP Imaging (NewTom 3G and VG, Elmsford, New York). Although both these machines—as all other CBCT machines—can export their volume data to third party software, DICOM (digital imaging and communication in medicine) data cannot be imported into the manufacturer's software for use with their templates and reporting tools. Although not a serious drawback, it is a point to consider when purchasing or using these machines. Third-party software is the biggest area of “growth” and is discussed below.

The most robust type of three-dimensional (3D) color software would include several parameters to assign to the voxel information. Every manufacturer and third-party software can handle the two-dimensional (2D) grayscale assignment to the voxel. Some even have algorithms to approximate Hounsfield units. Some third-party software can also perform surface rendering of the voxel units assigning a color to the voxel. You have seen many examples of gold, green, and even purple mandibles in implant planning software programs. A few vendors, for example Planmeca (Romexis, Helsinki, Finland) and Imaging Sciences (3DVR, Hatfield, Pennsylvania) and can assign a transparency value to each voxel to make a seemingly “transparent” image. A third-party company, Anatomage (San Jose, California) has this type of software and has created products for cephalometric landmark AnatoCeph tracing and implant planning (In Vivo Dental software, Anatomage, Inc., San Jose, California). Fig. 7 shows some of these products.

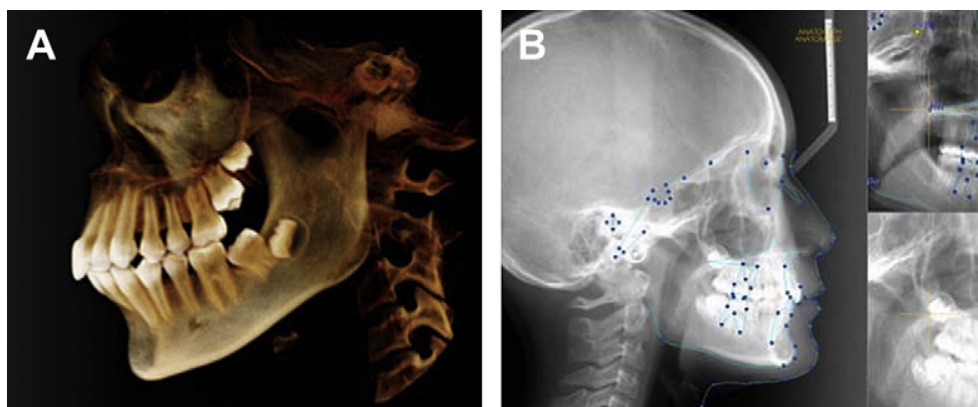


Fig. 7. (A) Typical 3D color reconstruction software with color and transparency shows course of IAN canal through the mandible. (B) Cephalometric tracing. (Courtesy of Anatomage, San Jose, CA. Available at: <http://www.anatomage.com>. Accessed June 27, 2008; with permission.)



The highest level of software treatment is able to assign color, transparency, and opacity values to the CBVT voxel information. To date, only OnDemand3D (CyberMed International, Seoul, Korea) can perform these tasks (Fig. 8).

Table 1 shows some of these third-party companies' products and capability.

### Useful software improvements

1. All software will be able to assign all 3 attributes—color, transparency, and opacity
2. Improved “scatter rejection” algorithms
3. All software completely DICOM compliant
4. Software in four dimensions to create the “Virtual Articulator”
5. Online, Internet “portal” software to speed surgical guide construction and delivery as well as interpretive reports and analytic images (eg, measured implant sites)
6. PACS/RIS systems for dentistry (see discussion below)

### Picture archiving and communication systems/radiographic information system radiographic information delivery

PACS have been developed and used in medicine for many years. The ability to store, retrieve, and share image information between medical specialists, including radiologists payers, administrators, and others, has

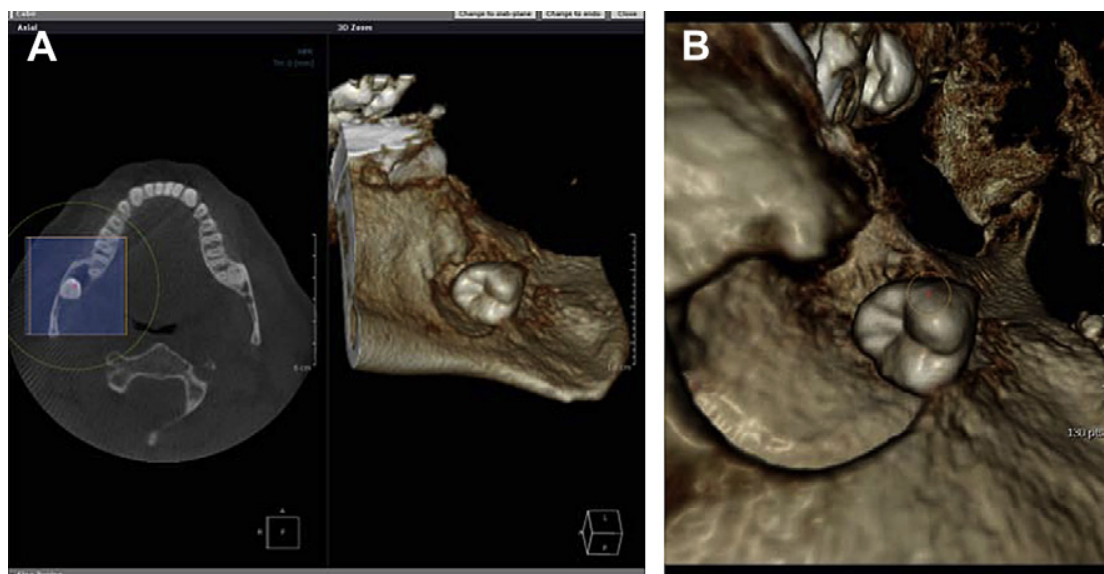


Fig. 8. (A) A 3D color reconstruction using transparency and opacity to show the occlusal surface of the third molar impacted in the bone! (Image created with OnDemand3D “Cube” tool, CyberMed, Seoul, Korea). (B) Same tooth as shown above but imaged with CyberMed’s “endoscopy” tool. Note the cuspal and developmental groove anatomy.

Table 1  
Oral and maxillofacial products and manufacturers

| Manufacturer          | Product name                          | Web site URL                                                                                                                                                           | Primary software task(s) |
|-----------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| 3dMD                  | 3dMDFace<br>3DMD<br>Cranial           | <a href="http://www.3dmd.com/home.asp">http://www.3dmd.com/home.asp</a>                                                                                                | Orthodontics             |
| Anatomage             | In Vivo<br>Dental<br>AnatoCeph        | <a href="http://www.anatamage.com/home.htm">http://www.anatamage.com/home.htm</a>                                                                                      | Implant, ortho           |
| CyberMed              | OnDemand3D<br>Vworks<br>Vceph         | <a href="http://www.cybermed.co.kr/eindex.php">http://www.cybermed.co.kr/eindex.php</a>                                                                                | Multiple                 |
| Dolphin               | Dolphin 3D<br>(OEM from<br>Anatomage) | <a href="http://www.dolphinimaging.com/new_site/home.html">http://www.dolphinimaging.com/<br/>new_site/home.html</a>                                                   | Orthodontics             |
| NobelBioCare          | NobelGuide                            | <a href="http://www.nobelbiocare.com/global/en/">http://www.nobelbiocare.com/global/en/</a>                                                                            | Implant                  |
| Materialise<br>Dental | SimPlant                              | <a href="http://www.materialise.com/materialise/view/en/84113-Dental+homepage.html">http://www.materialise.com/materialise/<br/>view/en/84113-Dental+homepage.html</a> | Implant                  |

grown an entire industry for these tasks. Until now, dentistry had only a couple of such products, and they were not widely used. Indeed, in the best of worlds, medical and dental records could be shared and distributed using PACS systems.

RIS is really just the information highway to deliver the radiologist's report to the referring hospital, clinician, or colleague. The two systems or products really go hand in hand.

Now there is a PACS/RIS product specifically for dentistry. CyberMed's OnDemand PACS/RIS was designed to handle the necessary data volumes, deliver reports, and analyses and archive client data off-site, one of the many, necessary Health Insurance Portability and Accountability Act (HIPAA) regulations. To date, it is the only HIPAA-compliant product I know of to use with our CBVT volumes. Remember that each patient case is 60 to 250 MB, depending on machine manufacturer. These large files must be moved quickly, safely, and efficiently without corruption. Dentistry has truly "made it to the big time" with this capability.

The PACS/RIS also does a lot more. Think of it as a "Practice Management System" for the office or laboratory. All dentists using cone beam, cone beam imaging laboratories, and single cone beam will use a PACS/RIS within 5 years.

### *Image-to-device processes*

Perhaps the most exciting area of dental and maxillofacial imaging will come in the area of device manufacture from 3D data using an "Online Distributive Network." Dentists want to be able to request or order

radiographic stents, surgical guides, study and orthodontic models, and other devices directly from their office computers.

Companies currently are raising venture capital to deliver these appliances and devices electronically. The Cone Beam image data makes this possible. Already we can see the patient's 3D color dentition. Many clinicians are sending their patient's data for surgical guide construction through companies like NobelBiocare. Larger surgical guides, requiring temporary horizontal "anchorage" to place multiple fixtures for overdentures can be received by mail or courier delivery. But, many more services, including faster, simpler delivery for single implant cases, will soon be offered through "Internet Portals" or distributive networks because of CBVT imaging. There are many more simple cases than complex cases.

## Summary

In summary, CBVT, as good as it is and will be, is a complementary technique to other more conventional imaging technologies. It offers our profession a substantial improvement for some but not all of our imaging tasks or need. For some procedures, it will become the standard of care.

Improvements in software removal of scatter artifacts; reduced x-ray dose; and delivery of interpretive reports, analyses, appliances, and images will continue, and use of CBVT will increase. Distributive networks will be introduced to simplify all of these tasks. Virtual articulators, computer assisted design and computer assisted manufacturing devices will improve, and online delivery of some of these services will increase concomitantly. In all, dentistry will improve and, along with it, patient care.

## References

- [1] Miles DA, Danforth RA. A clinician's guide to understanding cone beam volumetric imaging. Academy of Dental Therapeutics and Stomatology. Available at: [www.ineedce.com](http://www.ineedce.com).
- [2] Haiter-Neto F, Wenzel A, Gotfredsen E. Diagnostic accuracy of cone beam computed tomography scans compared with intraoral imaging modalities for detection of caries. *Dentomaxillofac Radiol* 2008;37:18–22.
- [3] Suomalainen A, Vehmas T, Kortetniemi M, et al. Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. *Dentomaxillofac Radiol* 2008;37:10–7.







# RESPONSE TO EDITORIAL ON AN AAOMR POSITION PAPER

INSCRIPTIONS, RUN IN DECEMBER 2012

**In their editorial**, Drs. Mufson and Ragan use the cliché “If all you have is a hammer, everything looks like a nail.” One might rephrase this as “If you are an oral maxillofacial surgeon, all you need is a panoramic.” In dentistry, unlike medicine, there is little evidence of science for some of the procedures we perform, and certainly very few precise protocols for those procedures. Unfortunately, dentistry is still more art than science. Some have even stated that “evidence-based dentistry” is really an oxymoron (the juxtaposition of two contradictory terms).

The two authors assert that the AOMOR position paper authors “failed to account for the fact that the overwhelming majority of dental surgical procedures performed on a daily basis, including removal or exposure of impacted teeth, sinus lifts, bone grafts, and yes also dental implants—especially in the hands of those with adequate training and experience—are performed successfully without the need for 3-D imaging”. It should be noted that none of these procedures, except implant imaging, requires any true level of precision. Oral maxillofacial surgeons can, because of their training in nature of their specialty, adequately perform flap procedures remove or recontour bone, and perform sinus lifts without precise measurements. Many, unfortunately, also think they can precisely and accurately place single or multiple implants with only a panoramic and “their hands.” It is sad to think that when an imaging modality such as CBCT is widely available, extremely precise, and capable of reducing patient morbidity from an implant procedure—even a single implant placement—and is not used<sup>3</sup>, and clinicians still think they do not need it.

Having examined the data volumes of over 13,000 CBCT cases, I can tell you I’ve seen hundreds of implants placed in locations, causing patient problems, which could have been avoided by simply using a better imaging modality than a panoramic. I’ve also been challenged by specialists who claim that there is no “case law” to prove to us that harm to the patient could have been avoided by using CBCT. While this is an accurate observation, it bears no resemblance to reality. There is no case law because these malpractice and negligence cases are settled out of court<sup>1</sup>. No dentist or dental specialist wants their name in the National Practitioner Database with a judgment against him or her for failing to use proper and appropriate imaging. This is the reality.

I have been involved in five such cases where damages to the patient could have been completely avoided by the appropriate use of CBCT for pre-surgical implant assessment. If I were the patient, wouldn’t I want 0.1mm accuracy, 1:1 anatomic reconstruction, and a surgical guide if necessary? Or would I choose a second surgical procedure because the initial one caused a perforation, parasthesia, or the need for implant retrieval from the antrum?

The authors’ arguments remind me of another quote, uttered in the House of delegates of the ADA, stricken from the record after an “in camera” session by ADA lawyers at an annual meeting on specialization (during the discussion on Oral and Maxillofacial Radiology as a new specialty),

“If we make radiology a specialty, then we (general dentists) will be held to a higher standard of care.”  
—anonymous general dentist, ADA House of Delegates, year unknown.

With all that said, I recognize the document was a position paper. The authors of the editorial recognized that “the document would be revisited periodically.” Dentists can choose to use a substandard, inferior imaging modality and “feel their way to success” if they wish. But, I submit, that these practices already increase their risk of litigation. It’s not “if” a mishap will occur—it’s “when”<sup>2</sup>.

—Dale A. Miles DDS, MS, FRCD(C), Dip. ABOMR

## REFERENCES

1. <http://www.dentalmal.com/implants.html>
2. [http://www.mccullochlaw.net/nerve\\_injury/cbct/index.html](http://www.mccullochlaw.net/nerve_injury/cbct/index.html)
3. Worthington P, Rubenstein J, and Hatcher D: The Role of Cone-Beam Computed Tomography in the Planning and Placement of Implants. *JADA*, 2010, Vol. 141, suppl. no. 3; pp: 19s-24s.





## Interpreting the **CBCT** Data Volume in Orthodontic Cases **Part 1**

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# Part 1: Interpreting the CBCT Data Volume in Orthodontic Cases: *You Should See What You May Be Missing!*

by Dale A. Miles, DDS, MS, FRCD(C)

This is a two-part article designed to help clinicians understand the more common findings they will encounter in the anatomic regions they capture in larger field-of-view (FOV) CBCT machines. Many of these findings will also be seen in smaller FOV machines when the volume capture is moved around to view things like the temporomandibular joint or third molar regions. So this article will be of interest to all clinicians, not just orthodontists. Part I will address the skull, oropharynx, cervical soft tissues and cervical spine. Part II will cover the paranasal sinus regions, nasal cavity, sella tursica region and TMJ. Anyone who owns or uses the data from a CBCT machine will see these pathologic findings and need to recognize them. Some findings are incidental but reportable/recordable. Many cited in this article can significantly impact the patient's health and after finding them, the patient must be referred to a medical specialist for further evaluation and management. Some might even save your patient's life. Missing the most important findings could lead to harm to the patient and result in litigation. All of this information will benefit both you and your patients.

## Introduction

It should be intuitively apparent to the orthodontist that there are important structures to examine beyond the dentoskeletal bases in any cone beam data volume that require interpretation. Typical anatomic structures that need to be examined in each volume include the:

1. skull and its contents
2. oropharyngeal tissues
3. cervical soft tissues
4. cervical spine
5. paranasal sinuses
6. nasal cavity
7. sella tursica and parasellar regions
8. temporomandibular joint complexes

This article will instruct the orthodontist on the methodology of examining these important anatomic regions and illustrate some of the more frequent findings in each of these areas. Some of the findings might simply be noteworthy and some will inevitably lead to referral either to another dental specialist or a medical provider. All of the figures seen in this article come from the author's radiology practice; that is, CBCT volumes referred by dentists and dental specialists using CBCT.

## The Skull and Its Contents

Most commonly there are physiologic calcifications seen within the skull on large field-of-view CBCT machines. These include the more common calcifications of the pineal gland, choroid plexuses and falx cerebri. Although calcification of the falx cerebri is seen in the nevroid basal cell carcinoma syndrome (Gorlin-Goltz) it is, nevertheless, a common finding, about 10 percent of the general population,<sup>1</sup> unassociated with a syndrome. Figure 1 is an example of such a normal falx finding.

Pineal gland calcification is usually physiologic in nature, occurring in about 40 percent of the general population by age 20.<sup>2</sup> Pineal calcifications less than 1cm in diameter are considered to be normal. Calcifications greater than 1cm could indicate a lesion in the pineal gland.<sup>2</sup> Figure 2 shows normal, physiologic calcification of the pineal gland

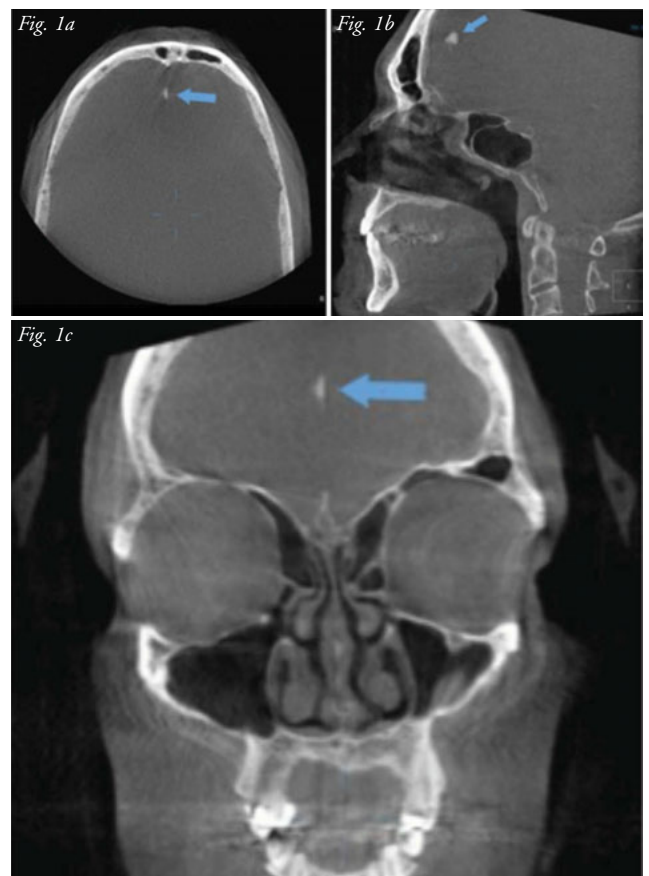


Fig. 1: (a.) Calcification of the falx in an axial view. (b.) In a sagittal view. (c.) In a coronal view. All slices are at 0.1mm thickness.



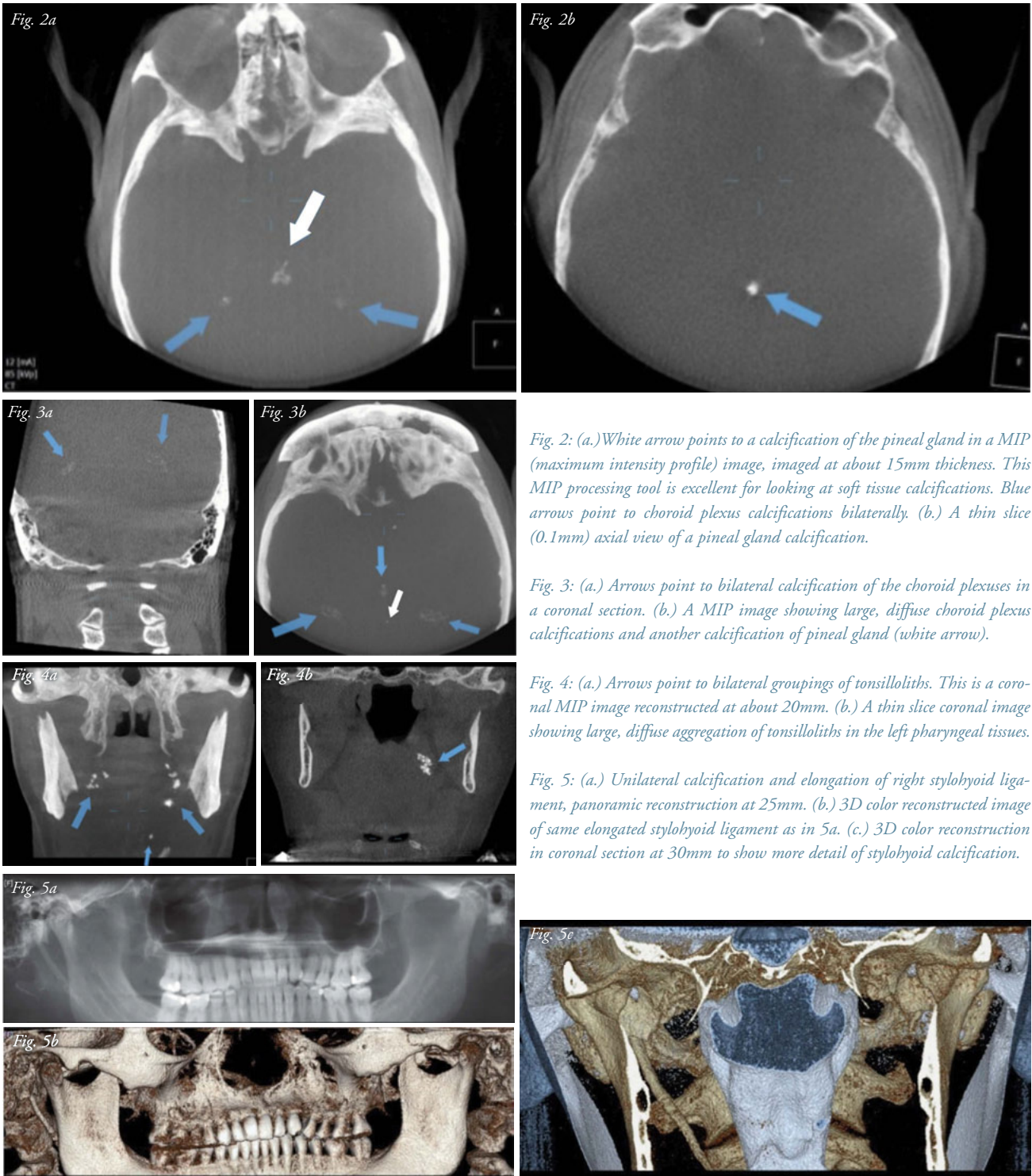
Calcification of the choroid plexuses is usually bilateral and is only worrisome if “exuberant” calcification is seen in young children.<sup>1</sup> Figure 2 and 3 below show physiologic choroid plexus calcifications.

Oropharyngeal Tissues

Tonsilloliths are common findings either unilaterally or bilaterally in the pharyngeal tissues. These calcifications can

occur singly or in clusters. Although all are noteworthy, multiple calcifications can be a source of malodor for the patient,<sup>3</sup> often undiagnosed in the dental office. They can cause repeated inflammatory problems and even ulcerate to the surface of the tonsillar crypt tissues.<sup>3</sup> Figure 4 illustrates more florid examples of tonsilloliths.

Although not specifically in the oropharyngeal airway space, the components of the stylohyoid ligament chain are



found adjacent to this region and calcification of some or all of their parts can lead to symptoms 4-6. Calcified elongated stylohyoid ligaments are quite common in any age group. It is only when symptoms arise that treatment is indicated. Figures 5 and 6 illustrate unilateral and bilateral cases. Eagle's syndrome has two presentations: the classic or more common is the feeling of a sharp pain like a fishbone in the throat upon swallowing (dysesthesia), the second presentation is one of a dull pain in the throat with radiating pain to the parietal, supra-orbital or infra-orbital regions.<sup>7</sup>

## Cervical Soft Tissues

In the cervical region in CBCT examinations the most important pathologic finding to recognize are calcifications in the carotid arteries either unilateral or bilateral. Sclerotic plaques associated with hypertension and increased stroke potential have been seen on panoramic images and reported for many years.<sup>8-10</sup> Although some are bilateral most are seen on one side of the image only. Many are probably missed on conventional panoramic because of the positioning of the focal trough in some machines; however, none should be missed on CBCT images. Bilateral, circumferential calcifications of the carotid arteries in the neck region sometimes in conjunction with concomitant parasellar calcifications of the internal carotid will be found within CBCT volumes. A subgroup of the larger numbers of carotid plaques these bilateral circumferential findings might indicate Medial Arterial Calcification (MAC) seen an undiagnosed or uncontrolled type II diabetes mellitus possibly in patients with end stage renal disease (ESRD).<sup>11-13</sup> Figures 7 to 9 illustrate cases with calcifications of the carotid arteries, routinely found in CBCT data volumes.

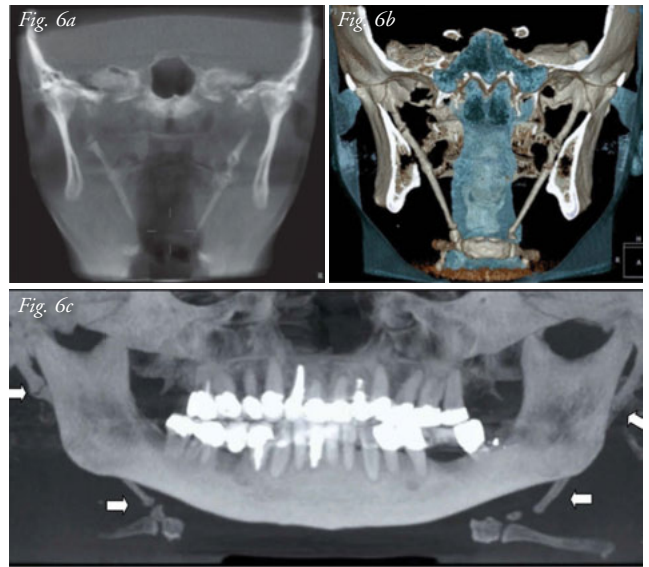


Fig. 6: (a.) Bilateral calcification and elongation of the stylohyoid ligaments. A coronal section reconstructed at about 10.0mm. (b.) 3D color reconstruction at 3mm details perfectly this rare total calcification of all elements of the stylohyoid ligament chain. (c.) A MIP image of the bilateral calcifications (white arrows).

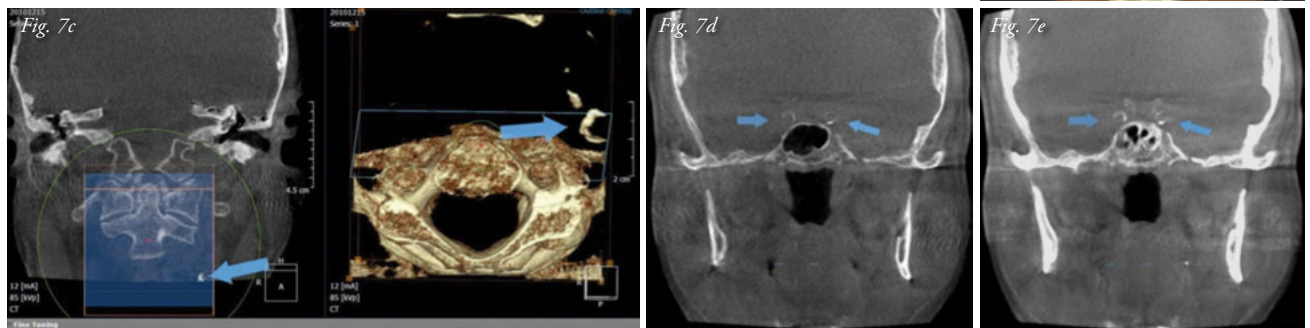


Fig. 7: (a.) Large calcification of the left carotid artery at the level of C3/C4. (b.) 3D color reconstruction of the same calcification seen in 7a. (c.) 3D color reconstruction using the "Cube" image processing tool and OnDemand 3D (CyberMed International, Seoul, Korea and Irvine, California) viewed from the coronal (left side) caudal (right side) positions. (d.,e.) Bilateral circumferential calcifications of the internal carotid artery in the parasellar region seen in a thin slice (1.0mm) coronal section and a thick slice (5.0mm) MIP image.

Fig. 8: (a.) Bilateral circumferential calcifications of the left and right carotid arteries. (b.) MIP reconstruction demonstrating the same calcifications at the level of C3/C4.





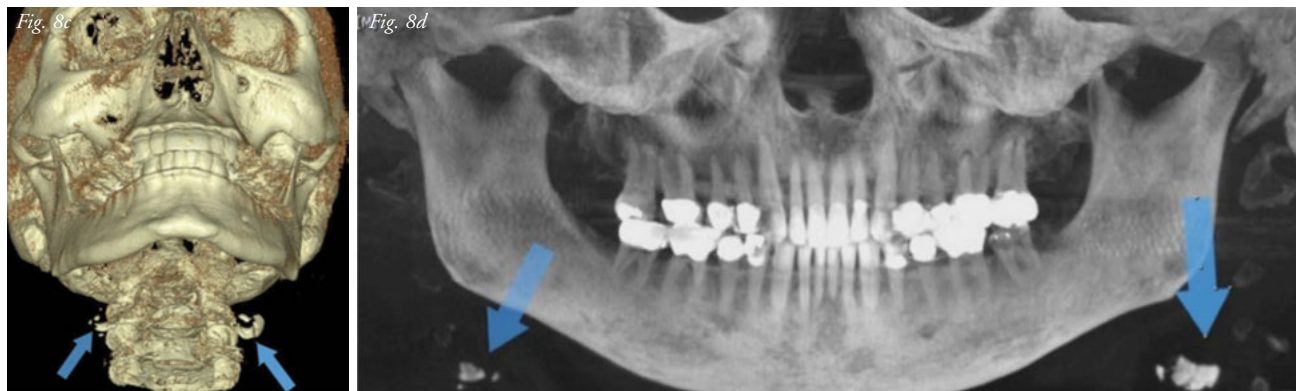


Fig. 8: (c.) 3D full color reconstruction of the patient's skull demonstrating bilateral carotid calcifications. The left appears quite circumferential. (d.) Panoramic MIP image reconstructed at about 35mm showing bilateral calcifications but no indication that they are circumferential as in 8a and 8c.

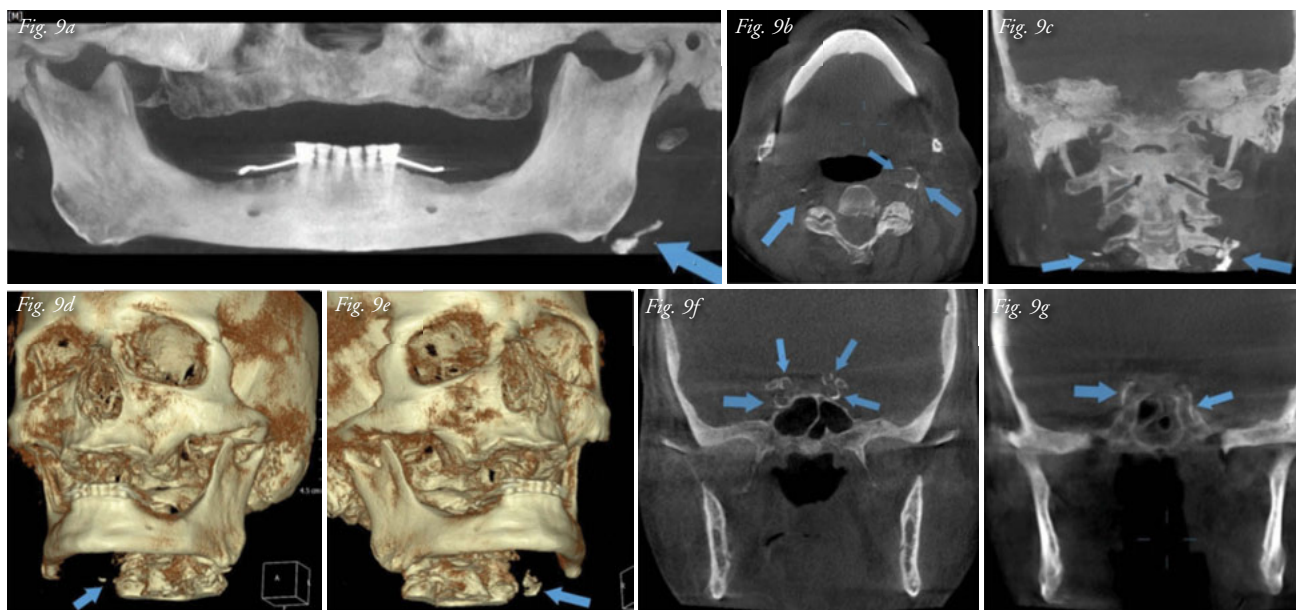


Fig. 9: (a.) Reconstructed Panoramic MIP image (35mm) demonstrating the large calcification on the patient's left side. There is no indication of any involvement of the right carotid artery even at this focal trough thickness. (b.,c.) Axial and coronal images showing calcifications of each side. (d.,e.) 3D color reconstructed views of the left and right side. (f.) Circumferential calcifications around curves segments of internal carotid in the parasellar regions bilaterally. (g.) Calcifications along the length of the internal carotid artery bilaterally has occurs from inferiorly to superiorly.

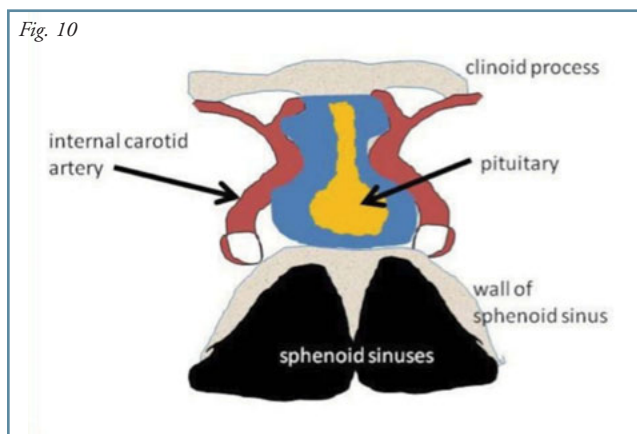


Fig. 10: Drawing of parasellar region showing relationship of internal carotid artery to pituitary fossa (sella tursica). Compare this drawing with figures 9f and g.

## Cervical Spine

Of course the most common changes found in the cervical spine are those that we also see in the TM joint complex. These include subchondral sclerosis, subchondral cyst formation, loss of joint space and osteophyte formation. Occasionally we also see a "loose body," especially at the atlantoaxial junction and less commonly calcification of the paraspinal ligaments especially the anterior. What is probably not appreciated by the orthodontist or dentist are that most of these changes are also seen in the facet joints, and not just the vertebral bodies. The examples in figures 11 to 13 (see next page) show most of these changes. In more than 9,000 CBCT cases that I have reviewed to date there also have been several lesions of the vertebral bodies, including possible metastatic lesions.

This course concludes in *Orthotown Magazine* next month. ■

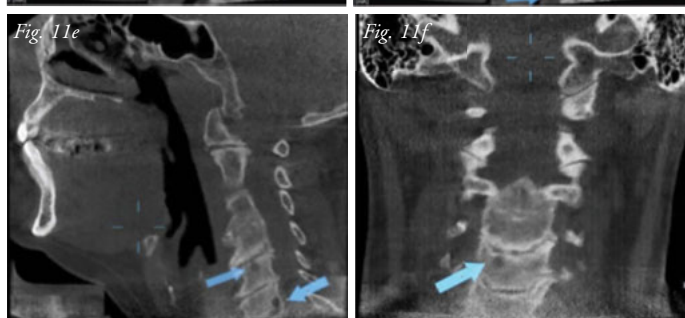
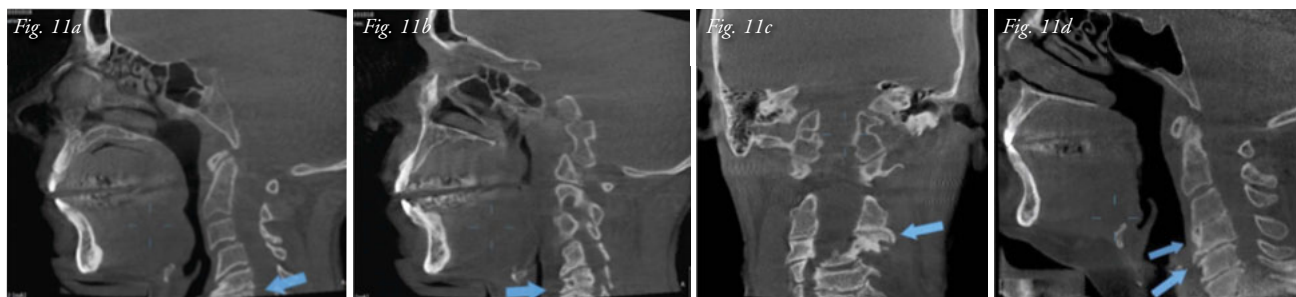


Fig. 11: (a.,b.) Loss of joint space osteophyte and subchondral cyst formation are seen in the vertebral bodies C5 and C6. (c.) Remodeling and loss of joint space seen in the right facet joint between C3 and C4 and the same case. (d.-f.) Similar changes in another case in the vertebral body C3 to C7. The osteophyte formation loss of joint space are consistent with osteoarthritis. The subchondral cyst formation seen in the vertebral bodies C4 and C5 are then most likely consistent with osteoarthritic changes. However, multiple site involvement of these radiolucent areas could also be consistent with metastases.

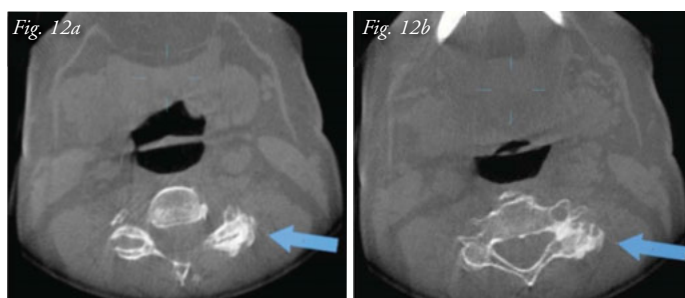


Fig. 12: (a.,b.) Gross remodeling subchondral sclerosis and subchondral cyst formation seen in the left facet joint between C3 and C4. (c.,d.) Loss of joint space, subchondral cyst formation, osteophyte formation and a loose body at the atlanto-axial junction are seen in this case. In addition there is a reverse curvature at the level of vertebral body C3 and C4 consistent with a cervical lordosis. In this case both the vertebral bodies in facet joints show comparable changes. All are consistent with osteoarthritis.

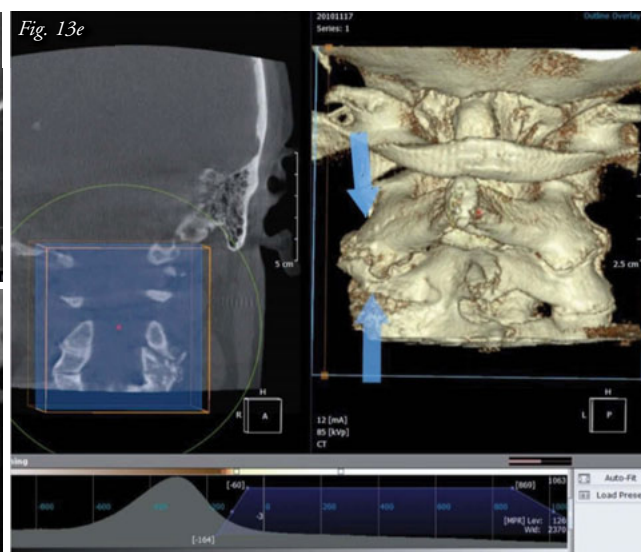
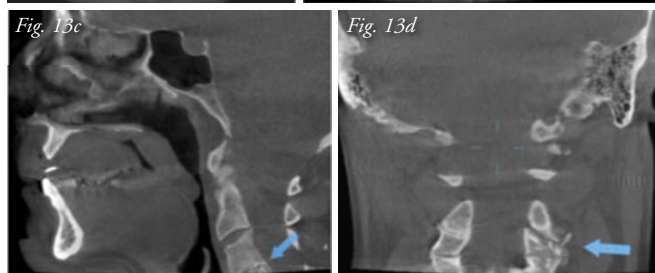
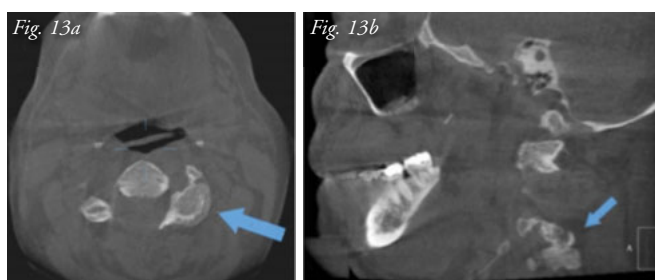


Fig. 13: (a.) An unusual change in the left facet joint between C3 and C4. The enlargement and mixed appearance of the lesion suggest a bony tumor rather than osteoarthritic change. (b.) A thin slice sagittal view through a portion of the lesion almost suggests some multilocularity. (c.) The radiolucency seen in the superior aspect of C4 is suggestive of a simple subchondral cyst. However, the changes seen in figure 13d in the facet joint are not consistent with osteoarthritic change. (e.) A 3D color reconstruction shows a gross remodeling of this left facet joint. The diagnosis of this particular lesion is not known at this time.



## References

1. Kiro lu Y, Çallı C, Karabulut N, and Öncel C: *Diagn Interv Radiol DOI*, 2009; online: [http://www.dirjournal.org/pdf/DIREPUB\\_2626\\_online.pdf](http://www.dirjournal.org/pdf/DIREPUB_2626_online.pdf)
2. Makariou E and Patsalides AD: Intracranial calcifications, 2009, 38 (11): online <http://www.appliedradiology.com/Issues/2009/11/November-2009.aspx>
3. Shetty D, Lakhkar B, Shetty CM. Images : Tonsillolith. *Indian J Radiol Imaging* 2001;11: 31-2.
4. Eagle WW. Elongated styloid process. Report of two cases. *Arch Otolaryngol*. 1937;25:548-587.
5. EAGLE WW. Elongated styloid process; symptoms and treatment. *AMA Arch Otolaryngol*. 1958; 67:172-176.
6. Langlais RP, Miles DA, Van Di ML. Elongated and mineralized stylohyoid ligament complex: A proposed classification and report of a case of Eagle's syndrome. *Oral Surg. Oral Med. Oral Pathol* 1986; 61:527-532.
7. Rinaldi , Cassale, M and Faiella F: Eagle Syndrome. March, 2010. <http://www.emedicine.com/article1447247-overview>.
8. Friedlander and Lande, *Oral Surg* 1981;52:102.
9. Friedlander and Baker, *JADA* 1994; 125:1598.
10. Carter et al, *Oral Surg* 1997;84: 697.
11. Lehto S, Niskanen L, Suhonen M, Ronnemaa T and Laakso M: Medial Arterial calcification A Neglected Harbinger of Cardiovascular Complications in Non-Insulin-Dependent Diabetes Mellitus Arterio, *Thromb and Vasc Biol* 1996;16:978.
12. Miles DA: Interpreting the Cone Beam Data Volume for Occult Pathology, *Seminars in Orthodontics* 15(1): 70-76, 2009.
13. Miles, DA: *Color Atlas of Cone Beam Volumetric Imaging, First Edition, Quintessence Publishing*, pp255-272, 2009.

## Author's Bio



**Dale A. Miles** is a professor of radiology at the Arizona School of Dentistry & Oral Health and an adjunct professor at University of Texas, San Antonio. He has previously held several prestigious positions, including, associate dean for clinical affairs at Arizona, chair of the Department of Oral Health Sciences at the University of Kentucky and graduate program director of Diagnostic Sciences at Indiana University. He is a diplomate of the American Board of Oral and Maxillofacial Radiology and the American Board of Oral Medicine. Dr. Miles has been named one of the "Top 100 Clinicians in CE" for the last eight years by Dentistry Today. He has authored more than 130 scientific articles and five textbooks, including the latest on Cone Beam Imaging. He has been a consultant to the U.S. Navy Postgraduate Dental School in Oral Diagnosis, Oral Medicine and Oral Radiology for more than 15 years. Dr. Miles has a Web site for teaching dentists and auxiliaries about digital imaging at [www.learn.digital.net](http://www.learn.digital.net). He is in full-time practice of oral and maxillofacial radiology in Fountain Hills, Arizona. To date he has read more than 10,000 cone beam CT scans for dental clients.

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1. All of the following pathoses might be seen in the soft tissues of the neck and pharyngeal regions EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. tonsillolith(s)
  - b. CESLs (calcified elongated stylohyoid ligaments)
  - c. carotid plaques
  - d. sialoliths
2. All of the following physiologic calcifications might be seen in the cranial vault EXCEPT ONE. Which ONE is the EXCEPTION? Calcifications of the:
  - a. pineal gland
  - b. choroid plexus(es)
  - c. internal acoustic meatus
  - d. falx cerebri
3. Intimal calcifications (plaques in the tunica intima of an artery) of the carotid artery seen in the cervical soft tissues at the level of C3/C4 can be associated with all of the following EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. stroke
  - b. hypotension
  - c. renal disease
  - d. Addison's disease
4. In addition to the more common location for carotid artery plaques seen in the cervical soft tissues in a CBCT scan, carotid plaques might also be seen in the following location:
  - a. adjacent to the foramen ovale
  - b. in the common carotid artery
  - c. in the parasellar region
  - d. near the internal acoustic meatus
5. According to some studies, pineal gland calcifications occurred in what percentage of the general population?
  - a. 10%
  - b. 20%
  - c. 30%
  - d. 40%
6. All of the following are clinical features of MAC (medial arterial calcification) EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. most commonly bilateral
  - b. associated with type II diabetes mellitus
  - c. associated with type I diabetes mellitus
  - d. associated with the ESRD (end stage renal disease)
7. Although calcification of the falx cerebri is a common or incidental anomaly, it can be found as part of which genetic syndrome?
  - a. Gorlin-Holtz syndrome
  - b. Nevroid basal cell carcinoma syndrome
  - c. Chediak-Higashi syndrome
  - d. Sjögrens syndrome
8. All the following are sites of osteoarthritic change EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. pedicles
  - b. spinal facet joints
  - c. atlanto-axial junction
  - d. none of the above
9. Calcified, elongated stylohyoid ligaments can be associated with which of the following?
  - a. Eagle's syndrome
  - b. Behcet's syndrome
  - c. Ernest's syndrome
  - d. Auriculo-temporal syndrome
10. William Eagle described two distinct syndromes. The second type was associated with all of the following symptoms EXCEPT ONE. Which ONE was the EXCEPTION?
  - a. dull throat pain
  - b. orbital region
  - c. parietal pain
  - d. dysethesia

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## Interpreting the CBCT Data Volume in Orthodontic Cases Part I

by Dale A. Miles, DDS, MS, FRCD(C)

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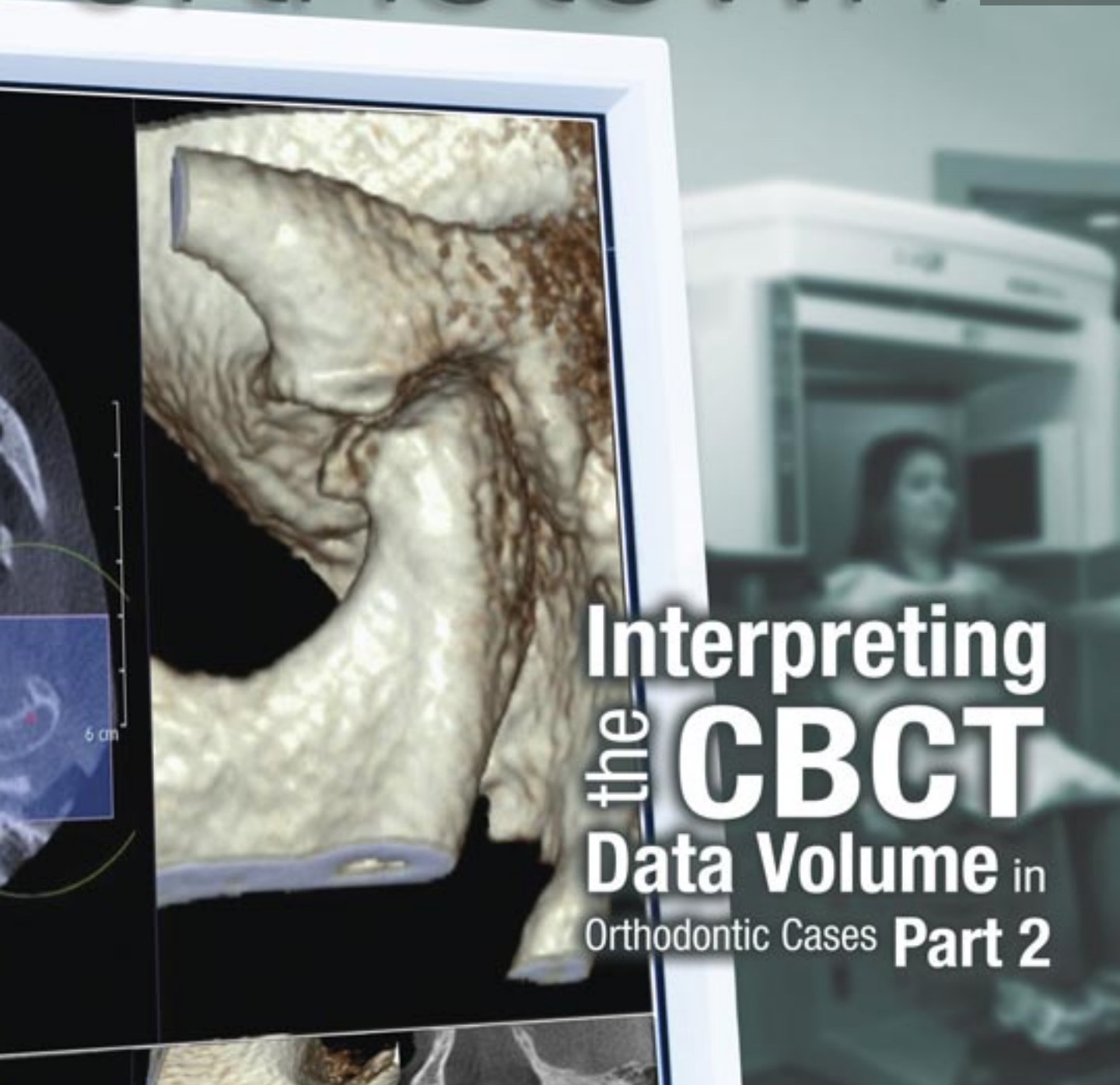
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## Interpreting the **CBCT** Data Volume in Orthodontic Cases **Part 2**

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# Part 2: Interpreting the CBCT Data Volume in Orthodontic Cases: *You Should See What You May Be Missing!*

by Dale A. Miles, DDS, MS, FRCD(C)

This is a two-part article designed to help clinicians understand the more common findings they will encounter in the anatomic regions they capture in larger field-of-view (FOV) CBCT machines. Many of these findings will also be seen in smaller FOV machines when the volume capture is moved around to view things like the temporomandibular joint or third molar regions. This article will be of interest to all clinicians, not just orthodontists. Part I addressed the skull, oropharynx, cervical soft tissues and cervical spine and can be found on Orthotown.com or in the July/August 2011 issue of *Orthotown Magazine*. Part II will cover the paranasal sinus regions, nasal cavity, sella tursica region and TMJ. Anyone who owns or uses the data from a CBCT machine will see these pathologic findings and need to recognize them. Some findings are incidental but reportable/recordable. Many cited in this article can significantly impact the patient's health and after finding them, the patient must be referred to a medical specialist for further evaluation and management. Some might even save your patient's life. Missing the most important findings could lead to harm to the patient and result in litigation. All of this information will benefit both you and your patients.

## Part II: Paranasal Sinuses

The paranasal sinuses include the maxillary, sphenoid and frontal sinuses. Although not strictly sinus spaces, the ethmoid air cells are also included in this category. All of these spaces communicate with one another. Inflammatory changes are seen in all these spaces; however, the maxillary sinuses and ethmoid air cells seem to be involved more commonly. Frontal and sphenoid involvement is less common. Nevertheless if changes are seen in the sphenoid sinus region, because of the important neural, vascular and optic structures which travel in the parasellar region, referral to an otolaryngologist and/or the patient's primary care provider is mandatory. Inflammatory or infectious changes in the sphenoid sinus could disseminate rather rapidly because of the proximity of the neurovascular structures in this region. In addition diffuse headache symptoms are common with

paranasal sinus problems and can be confusing to delineate and diagnose. Most of the changes seen in the paranasal sinus region are from chronic inflammatory complaints. But, things like antroliths, foreign bodies and even osteoma can occur in any of these spaces. Furthermore, dental problem such as apical periodontitis and chronic periodontal conditions can affect the maxillary sinus and caused mucosal alterations. If the field of view (FOV) fails to include all of the paranasal sinus regions and substantial changes are seen in the more inferior spaces such as the maxillary sinus and ethmoids, it might be necessary to reimaging the patient or referred to an ENT specialist for clinical and endoscopic evaluation. The figures demonstrate some of these problems.

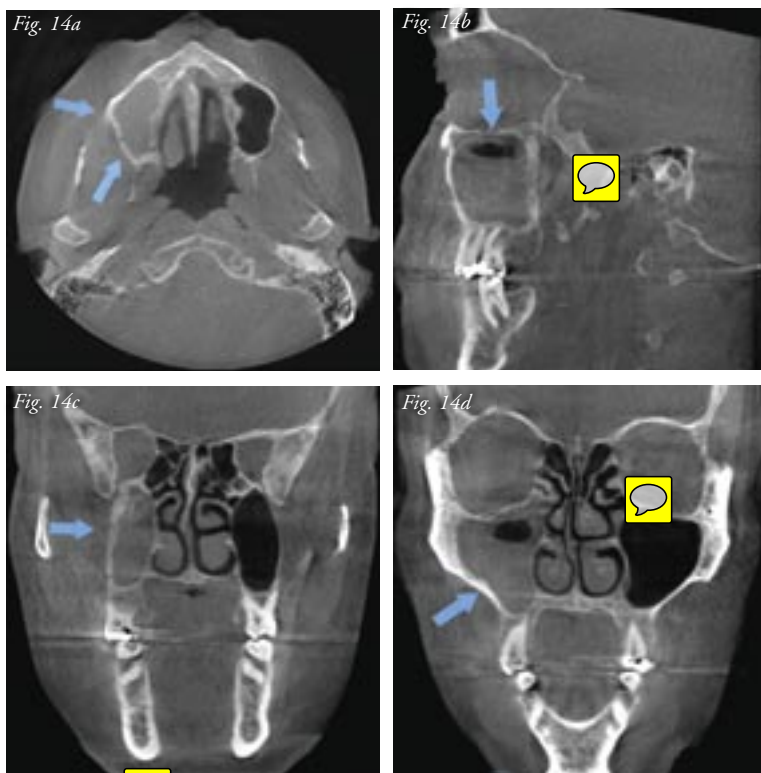


Fig. 14: (a) & (b) Blue arrows in the axial view and the white arrow in the sagittal view show a thickened lateral wall and a thickened posterior wall of the right maxillary sinus. The term for this is called "hyperostosis" and is indicative of a chronic inflammatory complaints or disease process. (c.) Hyperostosis is also seen in this coronal view of the right antrum. (d.) The white arrow shows to inflammatory change which is probably blocking the ostium (the communication between the maxillary sinus in the middle meatus). Blockages of this sort often lead to retrograde inflammatory change in the ethmoid air cells, frontal sinus and sphenoid sinus.

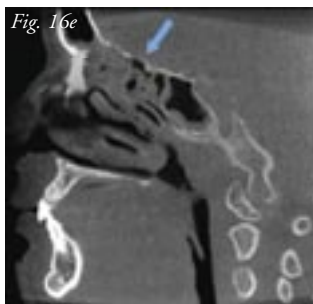
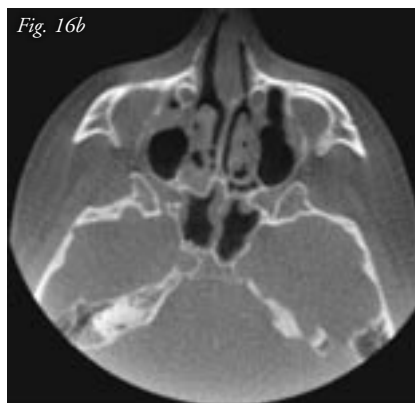
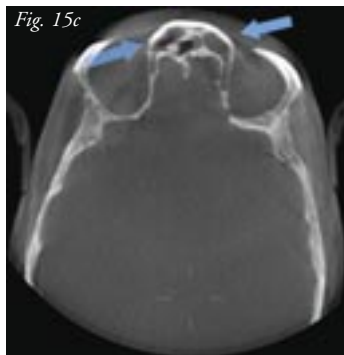
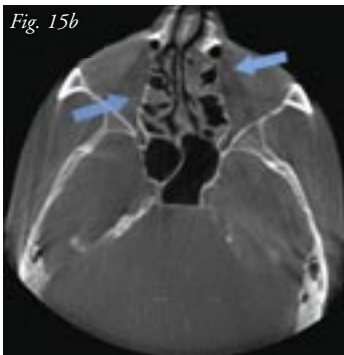


Fig. 15: (a.) A thin slice coronal view of maxillary antra and ethmoid air cell involvement. (b.) Axial view showing ethmoid air cell opacification seen in a. (c.&d.) Axial and coronal views of the frontal sinus involvement in the same case. Note the more florid involvement of the left frontal sinus.

Fig. 16: (a.) Bilateral maxillary sinus involvement (axial view). (b.) Axial view showing ethmoid air cell involvement in uniform thickening in sphenoid sinuses, both left and right. (c.) ethmoid air cell involvement more superiorly. (d.) Bilateral involvement of the frontal sinuses in an axial view. (e.) Inflammatory changes in the frontal sinus, ethmoid air cell region and sphenoid sinus. Note how these spaces communicate one with the other. (f.) Sagittal view of sphenoid sinus involvement in the same case. (g.&h.) Thin slice coronal sections showing bilateral maxillary sinus involvement and involvement of the superior ethmoid air cell complex as well as sphenoid sinuses again bilaterally.

## Nasal cavity

Anatomy of the nasal cavity is quite complicated. Besides typical structures like the turbinates and meatal shadows and nasal spine, there are additional anatomic structures like the uncinate process, the ostium, the ethmoid air cells, nasolacrimal ducts, sphenothmoid recess and frontal sinus ostium. Luckily, as in the paranasal sinuses, most abnormal things will be radiopaque. Below is

a state occurs commonly in the nasal cavity called “concha bullosa.” This is an aeration or pneumatization of the middle turbinate structure. It can be uni- or bilateral. When inflammatory change occurs in the nasal cavity, either originating there or spread from other paranasal sinus spaces, this can also have inflammatory problems. There are examples of both normally appearing concha bullosa and some with inflammatory change.

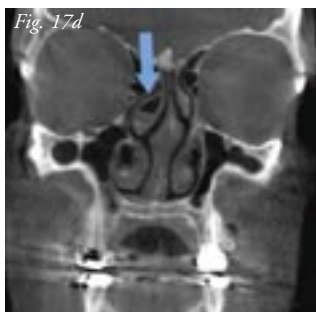
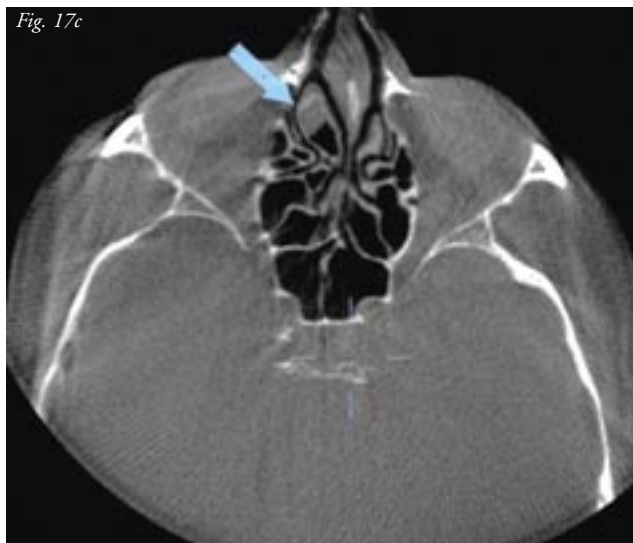
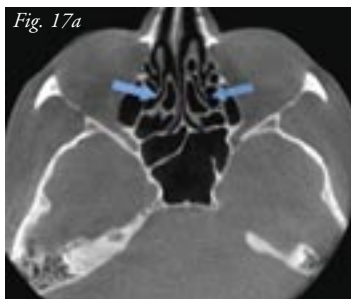


Fig. 17: (a.) Axial view of bilateral pneumatization states called concha bullosa (blue arrows). (b.) Unilateral concha bullosa state of left middle turbinate in coronal slice (blue arrow). (c.&d.) Inflammatory change filling one half of the concha bullosa anomaly in the right middle turbinate. (c.) Axial view (blue arrow); (d.) coronal view (blue arrow). (e.) Inflammatory material filling the right middle turbinate completely in an axial view. (f.) The same patient showing this change in a coronal slice. The left middle turbinate is patent. There is some mucosal thickening in the right antrum identified by the lowest blue arrow. (g.) A possible mucocele or pyocele in the superior ethmoid air cell complex. The round nature of the lesion suggests a fluid.

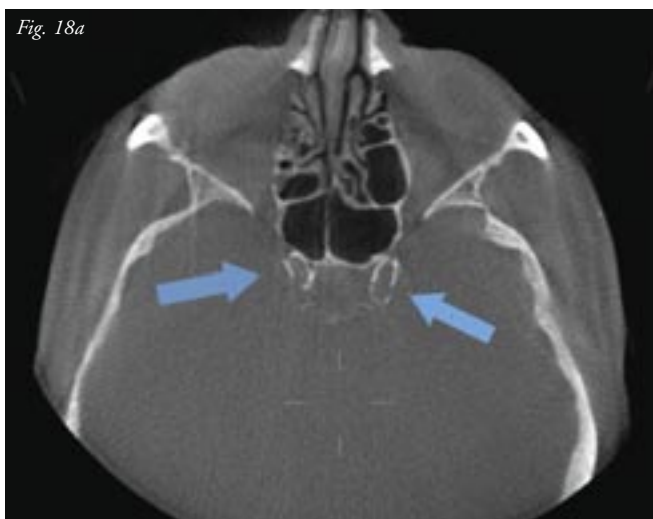
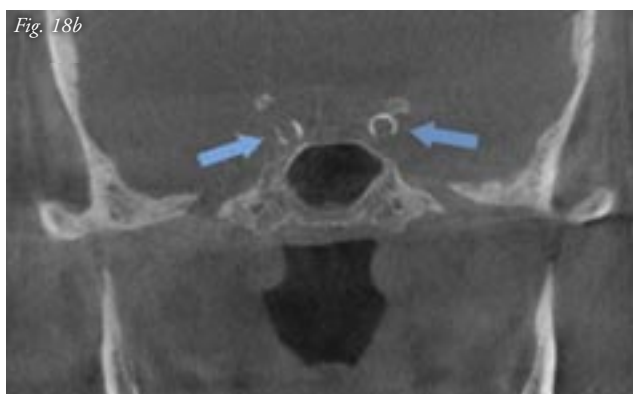


Fig. 18: (a.) Bilateral calcification of the internal carotid arteries on each side of the sella just posterior to the sphenoid sinus. (b.) The same calcifications as they loop anteriorly seen just superior to the sphenoid sinus and below the anterior clinoid processes.



### Sella Tursica and Parasellar Regions

Adenomas, craniopharyngiomas and disorders such as acromegaly can affect the size of the sella tursica.<sup>1</sup> However, to date, in more than 9,000 CBCT scans I have seen only one enlarged sella tursica but many parasellar changes as were described in the section on carotid calcifications; namely, calcification of the internal carotid artery. Since the contents of the pituitary fossa (sella tursica) can only be seen by magnetic res-

onance imaging, the clinician is more likely to see the parasellar changes. Figure 18 again illustrates the calcification seen in the internal carotid arteries. Since uncontrolled type II diabetes mellitus (NIDDM – Non Insulin Dependent Diabetes Mellitus), especially when the renal involvement is severe (as in ESRD – end stage renal disease), is so prevalent in the North American population, the clinician is more likely to discover calcified arteries rather than altered size of the sella tursica.



## Temporomandibular Joint Complexes

Of course the most common changes affecting the condylar head and sometimes the adjacent bone in the glenoid fossa are the same as those that affect the cervical spine and other weight-bearing joints.

These include:

1. osteophyte formation
2. subchondral cyst formation
3. subchondral sclerosis
4. surface erosion
5. lipping
6. loss of joint space

In addition to these changes of osteoarthritic, the clinician might also see hyper- or hypoplasia of one condylar head relative to the other, osteochondritis dissecans, avascular necrosis (AVN), loose body formation and occasionally synovial chondromatosis. In conventional 2D radiographic views such as panoramic or tomographic views loose bodies and even subchondral cyst formation can be misinterpreted. The focal trough layer or tomographic slice might not depict the true situation as can be seen in color 3D reconstructed views or even multi-planar views of the same joint. Figure 19 shows a number of these temporomandibular joint changes and disorders.

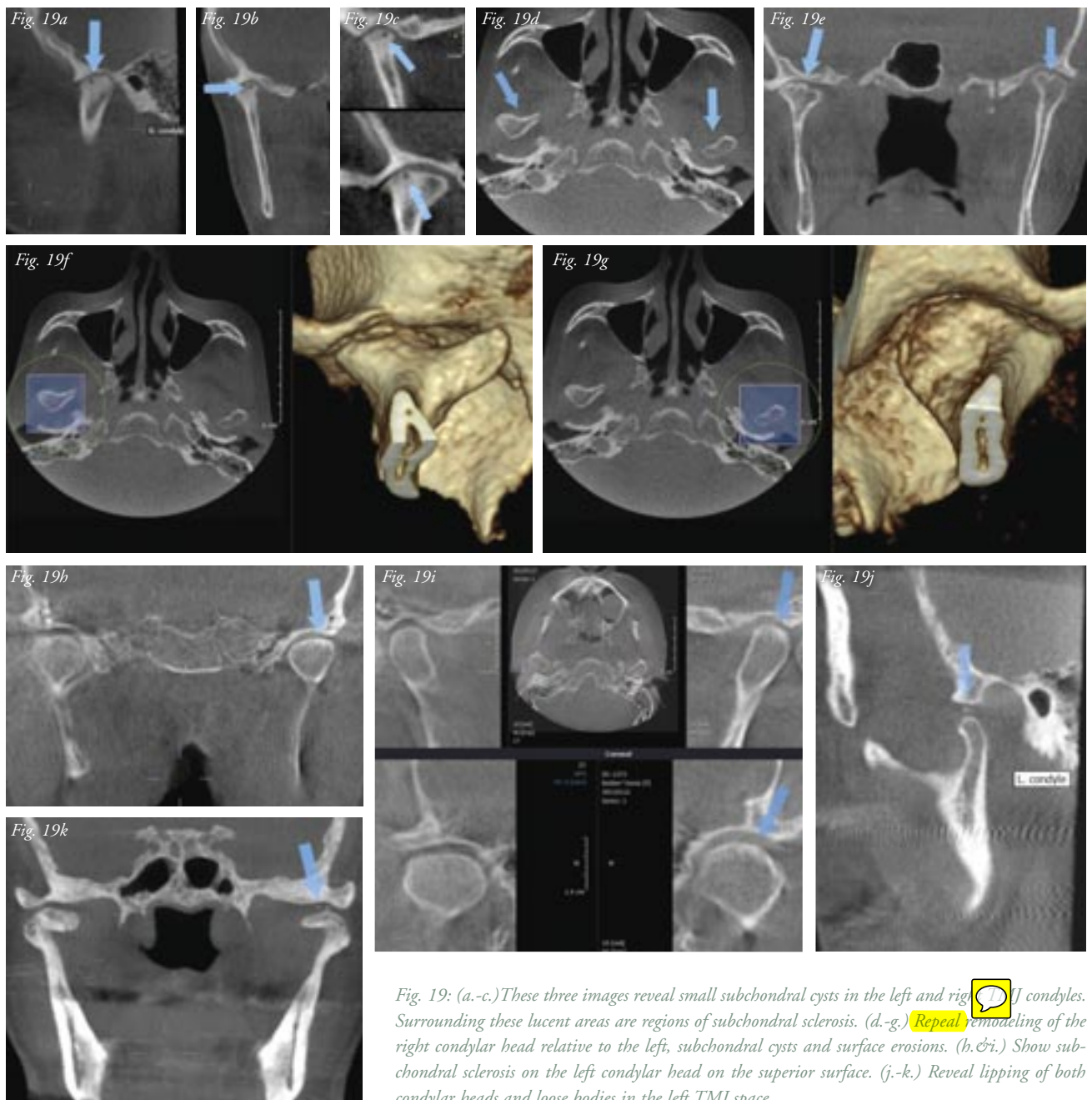
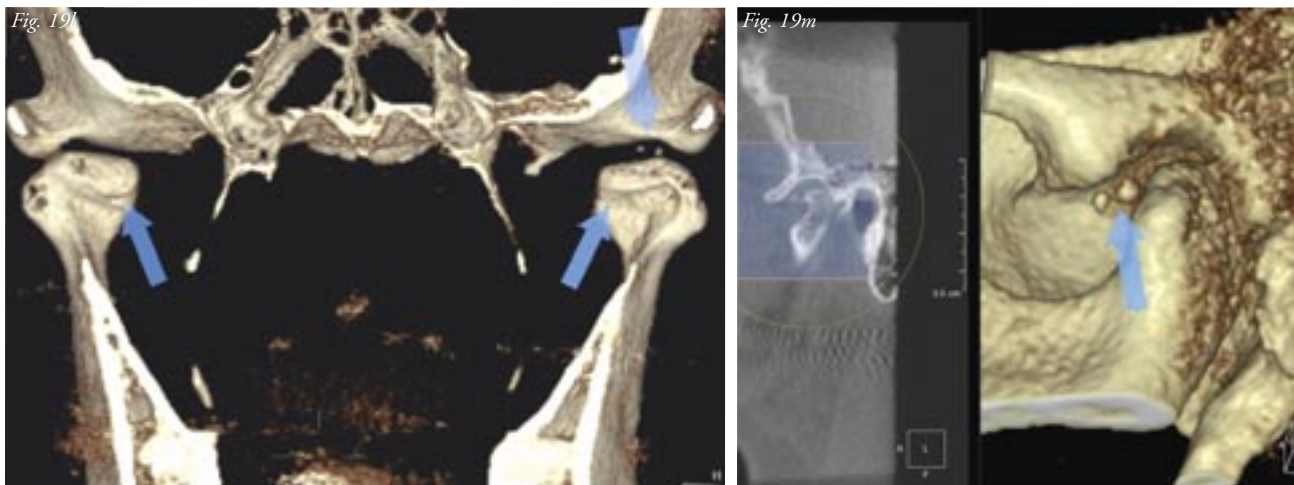


Fig. 19: (a.-c.) These three images reveal small subchondral cysts in the left and right TMJ condyles. Surrounding these lucent areas are regions of subchondral sclerosis. (d.-g.) Repeat remodeling of the right condylar head relative to the left, subchondral cysts and surface erosions. (h.-i.) Show subchondral sclerosis on the left condylar head on the superior surface. (j.-k.) Reveal lipping of both condylar heads and loose bodies in the left TMJ space.



Fig. 19: (l-m.) Reveal lipping of both condylar heads and loose bodies in the left TMJ space.



## Osteophyte vs. Lipping

Until clinicians were able to see the changes on the temporomandibular joint condyles in 3D reconstruction, the terms “bird-beak” and osteophyte were often used as synonyms in 2D planar imaging such as panoramic, lateral cephalometric and even tomographic slices. So-called “bird-beak” changes were interpreted as such when indeed many cases might have represented lipping<sup>3</sup> on the anterior aspect of the condyle, simply captured in a relatively thin slice, predominantly sagittal view. Figures 20a-c demonstrate this pitfall.

## Conclusions

Relatively common pathologic findings have been reviewed for the anatomic area seen in large FOV CBCT machines. While all of these findings are certainly reportable, there are only a few which are truly significant and would impact the systemic health of the patient. Significant findings such as calcification of arteries, airway masses, florid paranasal sinus disease and lucencies in the vertebral column could lead

to a catastrophic health event for the patient. Knowledge of these more common findings and normal anatomy of the region cited will help the clinician avoid a missed diagnosis and possibly a subsequent legal problem. Even though the clinician does not have to make a diagnosis based on the radiographic findings alone, he or she must examine the volume or refer for examination to an oral maxillofacial radiologist or other competent provider so that significant findings are not missed. This practice of referral is not only prudent, but also professionally mandated in the American Dental Association's Code of Ethics.<sup>4</sup> ■

## References

1. Kurnick JE, Hartman, CR, Edward G. Lufkin, EG and Hofeldt FD: A Tumor Board Review of the Clinical Significance Arch Intern Med. 1977;137(1):111-117.
2. Vinik AI and Vinik E: Advances in Diabetes Care: Prevention of the Complications of Diabetes Amer J Managed Care 2003; 9(3), Supplement.
3. Miles DA: The Good, the Bad and the Ugly, Implant Practice 2009, 2(3): 42-45.
4. [www.ada.org/sections/about/pdf/slada\\_code.pdf](http://www.ada.org/sections/about/pdf/slada_code.pdf) - 2010-04-30

All images were created using OnDemand3D software (Irvine, California and Seoul, Korea).



Fig. 20: (a.) This thin slice sagittal view of the left condylar head shows a pointed appearance on the anterior aspect resembling a “birds-beak.” (b.) This 3D reconstruction of the left condyle seems to mirror somewhat figure 19a. There appears to be a projection on the anterior surface which could be mistaken for an osteophyte. (c.) This 3D reconstructed coronal view reveals a deep pterygoid fovea and significant lipping of the anterior surface. There is no birds-beak or osteophyte on this condyle, simply unaltered surface morphology, deep depression and growth of the bone anteriorly.

## Author's Bio

**Dale A. Miles** is a professor of radiology at the Arizona School of Dentistry & Oral Health and an adjunct professor at University of Texas, San Antonio. He has previously held several prestigious positions, including, associate dean for clinical affairs at Arizona, chair of the Department of Oral Health Sciences at the University of Kentucky and graduate program director of Diagnostic Sciences at Indiana University. He is a diplomate of the American Board of Oral and Maxillofacial Radiology and the American Board of Oral Medicine. Dr. Miles has been named one of the "Top 100 Clinicians in CE" for the last eight years by *Dentistry Today*. He has authored more than 130 scientific articles and five textbooks, including the latest on Cone Beam Imaging. He has been a consultant to the U.S. Navy Postgraduate Dental School in oral diagnosis, oral medicine and oral radiology for more than 15 years. Dr. Miles has a Web site for teaching dentists and auxiliaries about digital imaging at [www.learn.digital.net](http://www.learn.digital.net). He is in full-time practice of oral and maxillofacial radiology in Fountain Hills, Arizona. To date he has read more than 10,000 cone beam CT scans for dental clients.



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1. Mucosal change in the maxillary sinuses can be caused by all of the following EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. apical periodontitis
  - b. chronic periodontitis
  - c. allergic sinusitis
  - d. antrolithiasis
2. Most commonly the changes seen in the paranasal sinuses are inflammatory; however, additional lesions can include all the following EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. cholesteatoma
  - b. osteoma
  - c. antrolith
  - d. none of the above
3. Blockage of the ostium most directly causes which of the following?
  - a. retrograde inflammation in the ethmoid air cells
  - b. retrograde inflammation in the maxillary sinuses
  - c. inflammation of the concha bullosa
  - d. inflammation of the frontal sinuses
4. Osteoarthritic changes of the temporomandibular joint condyles include all of the following EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. lipping
  - b. subchondral sclerosis
  - c. subchondral cyst(s)
  - d. synovial chondromatosis
5. Which of the following is the term used for a common state of the nasal cavity found in the middle turbinates?
  - a. nasal polyp
  - b. uncinata bulla
  - c. ivory osteoma
  - d. concha bullosa
6. In which of the paranasal sinus spaces is significant radiographic change, like opacification, a reason for immediate referral to the otolaryngologist?
  - a. ethmoid air cells
  - b. sphenoid sinus
  - c. frontal sinuses
  - d. none of the above
7. All of the following disorders can alter the size of the sella tursica EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. acromegaly
  - b. pituitary adenoma
  - c. craniopharyngioma
  - d. nasopharyngeal carcinoma
8. Radiographic changes of the temporomandibular joint condyles might be seen in all of the following disorders EXCEPT ONE. Which ONE is the EXCEPTION?
  - a. avascular necrosis
  - b. synovial chondromatosis
  - c. anterior disk displacement
  - d. none of the above
9. A "birds-beak" appearance in images of the temporomandibular joint is pathognomonic of osteoarthritic change.
  - a. True
  - b. False
10. Which of the following anatomic regions, seen in CBCT scans, is important to examine for possible calcification of the internal carotid artery?
  - a. cervical soft tissues near C5-C6
  - b. inside the sella tursica
  - c. the region of the dens
  - d. parasellar region

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6. a b c d
7. a b c d
8. a b c d
9. a b
10. a b c d





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# Interpreting the Cone Beam Data Volume for Occult Pathology

*Dale A. Miles*

Although digital x-ray adoption has been slow over the 20 years since its introduction, cone beam volumetric imaging (CBVI) or cone beam volumetric tomography (CBVT) has been employed very rapidly. Dentists will not replace all panoramic or intraoral procedures with CBVT, but the images and image data produced by this modality will help dentists perform many dental tasks more efficiently and confidently, tasks such as implant site assessment, visualizing temporomandibular joint structures and impaction problems among others. In short, dentistry, like medicine, will select the appropriate imaging modality for a specific diagnostic task—instead of trying to make one modality fit all tasks. Images and data sets will be moved between clinicians and laboratories rapidly and efficiently for diagnosis, second opinion, and even model and surgical guide construction as well as orthodontic models. Orthodontic analyses will eventually be performed with more accuracy in three-dimensional (3D) and 4D formats. This article attempts to predict in a limited way some of the imaging “standards of care” that will arise from the latest advancements in imaging and inform the reader of some issues yet to be resolved. (Semin Orthod 2009;15:70-76.) © 2009 Published by Elsevier Inc.

With the advent of the radiology technology called cone beam computed tomography imaging, dentistry has leapt forward in its diagnostic capability. Visualization of anatomy and pathology has now replaced radiographic interpretation. Dentists and dental specialists now have an imaging modality that rivals that of their medical colleagues. Where we once looked at “Rorschach tests,” which we called plain film radiographs, we now can look at two-dimensional (2D) and 3D color reconstructions of the region of interest which we need to consider in our diagnosis.

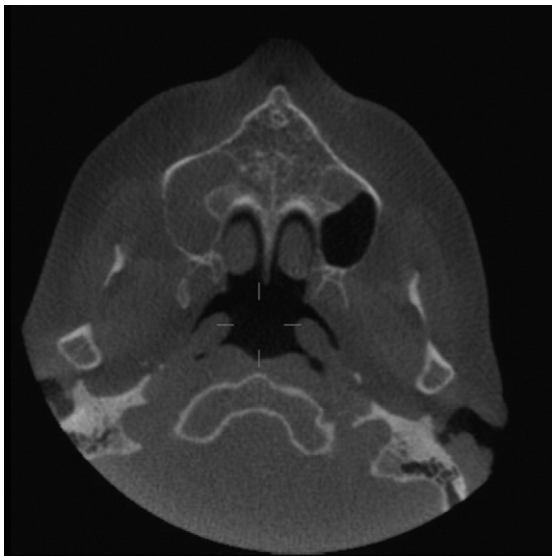
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With this dramatic improvement in imaging capability comes the obligation to look at much more clinical radiographic data to avoid missing a significant finding in what is termed the data volume. The data volume, which consists of the information that is acquired during the image acquisition process, can range in size for each patient from 99 MB to 250 MB of data. When we refer to the data volume, we are really referring to the myriad of slices obtained during the scan. Unlike looking at a single panoramic or supplementary radiograph, the clinician must now scroll through slices that can number over 500 in three separate planes of section, namely, axial, sagittal, and coronal. The dentist or dental specialist cannot abrogate this responsibility just by selectively looking at a region of interest such as an implant site. The entire data volume must be scanned and interpreted for reportable findings and occult pathology. This obligation extends also to the laboratory service or cone beam owner as well as the referring clinician. Both the owner of the image acquisition site and the clinician requesting the scan would be held ac-



**Figure 1.** An axial view showing mucosal change filling the right antrum entirely, and left partially at the level of the nasopalatine foramen. Other axial slices and additional views in other planes of section will completely characterize the changes, radiographically.

countable for a significant missed finding should the patient be harmed.<sup>1</sup>

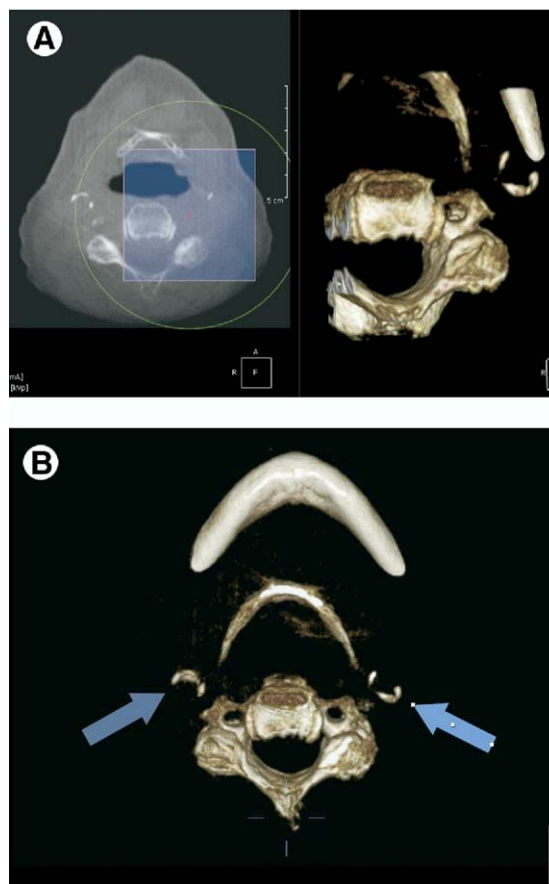
## Occult Pathology

When a volume is acquired, there is usually a prescribed reason for the dentist to order the “scan.” Implant site evaluation, orthodontic assessment, presurgical evaluation of an impacted third molar . . . all of these tasks (and many more) will eventually be routinely performed by CBVT (cone beam volumetric tomography). Specific data and images, produced by the scanner owner, are used by the referring clinician in an analysis to manage a patient’s problem or disease. However, in many cases, there are other findings that are “reportable” that could also affect the patient or their dental treatment. These findings, such as a sinus blockage, a calcified plaque, osteoarthritic changes in the vertebral bodies or temporomandibular joint (TMJ) condyle, or even a tumor, were not anticipated or suggested by clinical examination or the medical history. These findings are termed “occult”; that is, they are unanticipated and possibly harmful to the patient.

At the very least, occult findings can alter the treatment plan in many situations, requiring the

referring clinician to postpone their anticipated dental treatment to refer the patient to the primary care physician or medical specialist to evaluate and/or manage the finding before the dental treatment can resume. An example might be a pan-sinusitis in an implant patient (Fig 1). If the implant is to be placed in the maxilla and a sinus augmentation procedure anticipated, the paranasal sinuses need to have a “clean bill of health” before the surgery is planned.

At the other end of this spectrum of findings are problems that could affect the patient’s life. These findings do occur, and will no doubt increase in incidence as the adoption of CBVT



**Figure 2.** (A) Bilateral “circumferential” calcifications consistent with MAC (medial arterial sclerosis). The three-dimensional (3D) color reconstruction is of the patient’s left side where the red “x” is located. Image was created in OnDemand3D (CyberMed International, Seoul, Korea) using their “Cube” tool. (B) 3D color reconstruction showing “ring-like” calcifications bilaterally. (Color version of figure is available online.)

moves ahead. An example here is the finding of concentric or ring-like calcifications in a diabetic patient (Fig 2). These calcifications, called MAC (medial arterial sclerosis) signal a patient in or nearing ESRD (end stage renal disease), a condition that often leads to below-the-knee amputations in this diabetic population.<sup>2,3</sup>

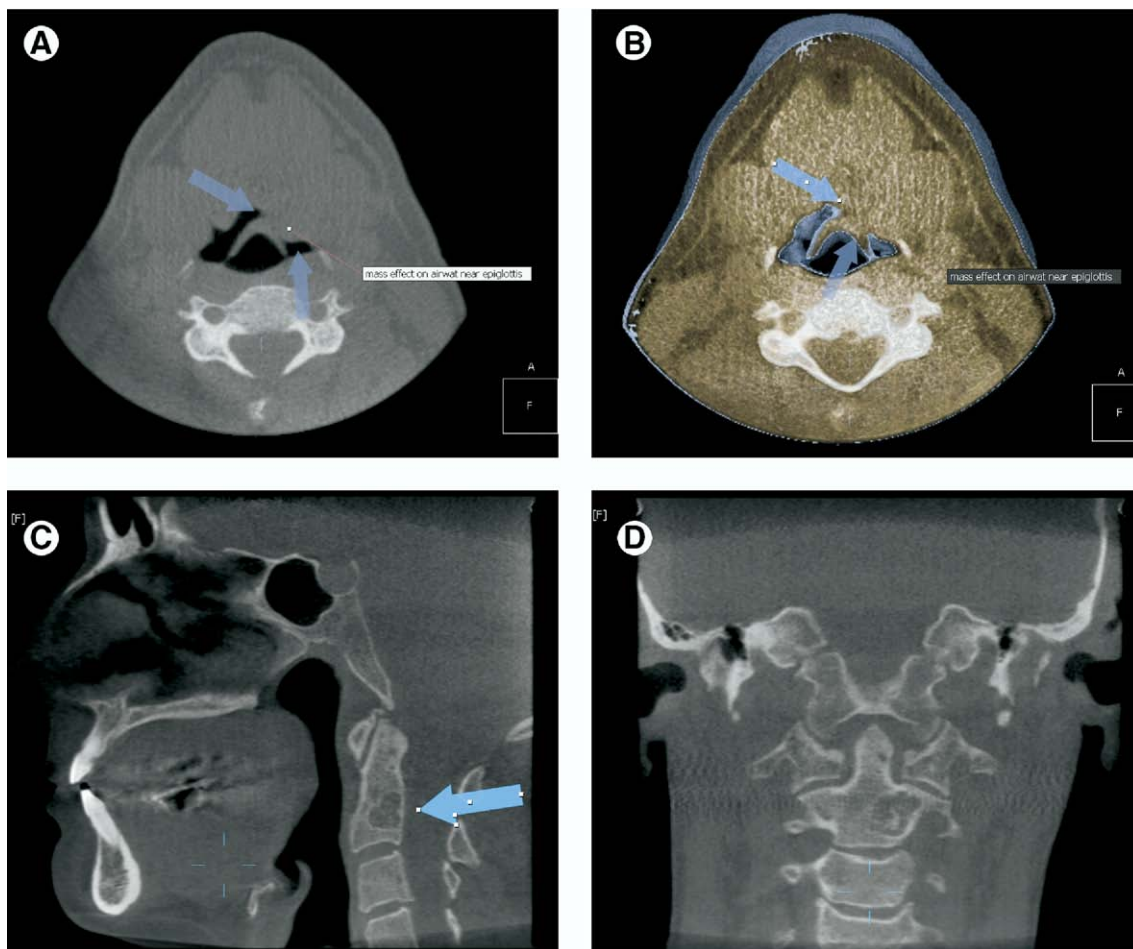
### Some Common Findings

A recent study reported the “reportable findings” in the first 380 cases I reviewed for multiple scanning sites.<sup>4</sup> Among these reportable findings were: congenitally missing teeth, calcified, elongated stylohyoid process(es), calcified lymph nodes, retained root(s), metallic frag-

ments, hypoplasias/hyperplasias (facial, TMJ, and teeth), medial sigmoid depression(s), dilacerated roots, tori, enostosis, SSGD (submandibular salivary gland depression), fibrous healing defect, and so forth.

“Boney” conditions reported in these patients included: numerous cases of “apical periodontitis” (not seen in the conventional images), residual cysts, furcation problems, recent extraction site(s), unanticipated impacted teeth, idiopathic osteosclerosis, and so on.

Significant “occult” findings included: one suspected case of Paget’s disease of bone, several implants impinging in anatomic spaces, 2 pharyngeal masses, 2 cases of a blocked ostium, several antral lesions, a suspected neurolem-



**Figure 3.** (A) Two-dimensional (2D), thin slice (0.15 mm) axial view from data showing a “mass effect” on the left pharyngeal tissues encroaching on the epiglottis. (B) A thickened “slice” (20 mm) 3D color reconstruction of the same “mass.” (C) A small multilocular lesion in vertebral body C-2 (odontoid process) suggestive of a “simple bone cyst” or “aneurysmal bone cyst.” (D) Coronal view of lesion in (c). (Color version of figure is available online.)

moma in the inferior alveolar canal, an undiagnosed fractured zygoma, and numerous vertebral changes including 2 surgical “repairs” of vertebrae. Figure 3(a) and (b) represent an example of a “mass” in the throat. Figure 3(c) and (d) show a vertebral body lesion that the patient and the doctor were not aware of—true “occult” pathology that will significantly impact the patient.

The differential diagnosis for the lesion seen in Fig 3(c) and (d) included:

1. Simple bone cyst
2. Aneurysmal bone cyst
3. Giant cell tumor

The inclusion of the vascular lesion mandated an aspirational biopsy and follow-up with computed tomographic (CT) and magnetic resonance (MR) imaging with and without contrast agent. The patient had been referred for a single dental implant site evaluation.

### Some Findings of Significance

Oral and maxillofacial radiologists receive training in many imaging modalities and pathologic conditions in the head and neck region, other than the dental bases. There are stored references for medical conditions that occur with some frequency in these scans to add at the end of an interpretive report as reference material for educating the dentist as to the “severity” of the finding and the need for referral—in some cases, immediately. Oral and maxillofacial radiologists also make specific referral and management recommendations when indicated by the radiographic findings.

The following are conditions seen sufficiently frequently to require IMMEDIATE referral recommendations:

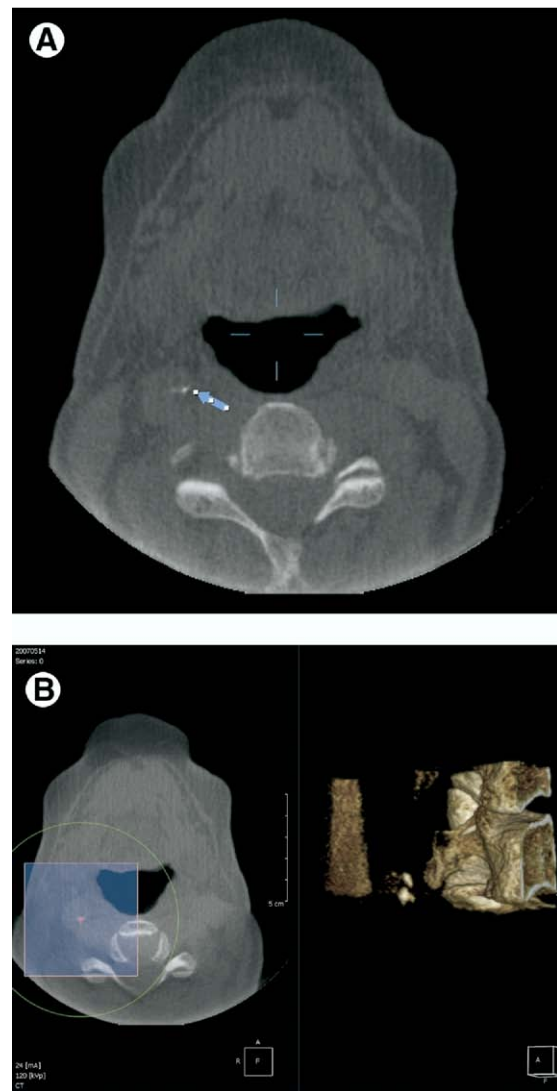
1. Calcified carotid plaques (Fig 4)
2. MAC—Monckeberg’s calcinosis
3. Paranasal sinus disease (Fig 5)
4. Suspected mucocele (Fig 6)
5. “Floating tooth” (Fig 7)

All of these conditions have significant morbidity associated with their presence and their management. Most of these also result in death or a significant change in the patient’s “quality of life.”

**Calcified carotid plaques.** It is well documented now that patients who have the dif-

fuse, irregularly shaped sclerotic plaques seen in the oropharyngeal airway on panoramic radiographs (and now with more clarity on CBVT) have a significant risk of hypertension and stroke.<sup>5</sup>

**Medial arterial sclerosis.** Probably more significantly, these calcifications are now very well-known predictors of early stage renal disease (ERSD), secondary to renal compromise. These patients will lose limbs if aggressive treatment is not instituted as soon as the calcifications are found.<sup>2,3</sup> Worldwide, diabetes mellitus will affect 300 million people by the



**Figure 4.** Two small calcifications in the left carotid region suggestive of sclerotic plaques. (Color version of figure is available online.)



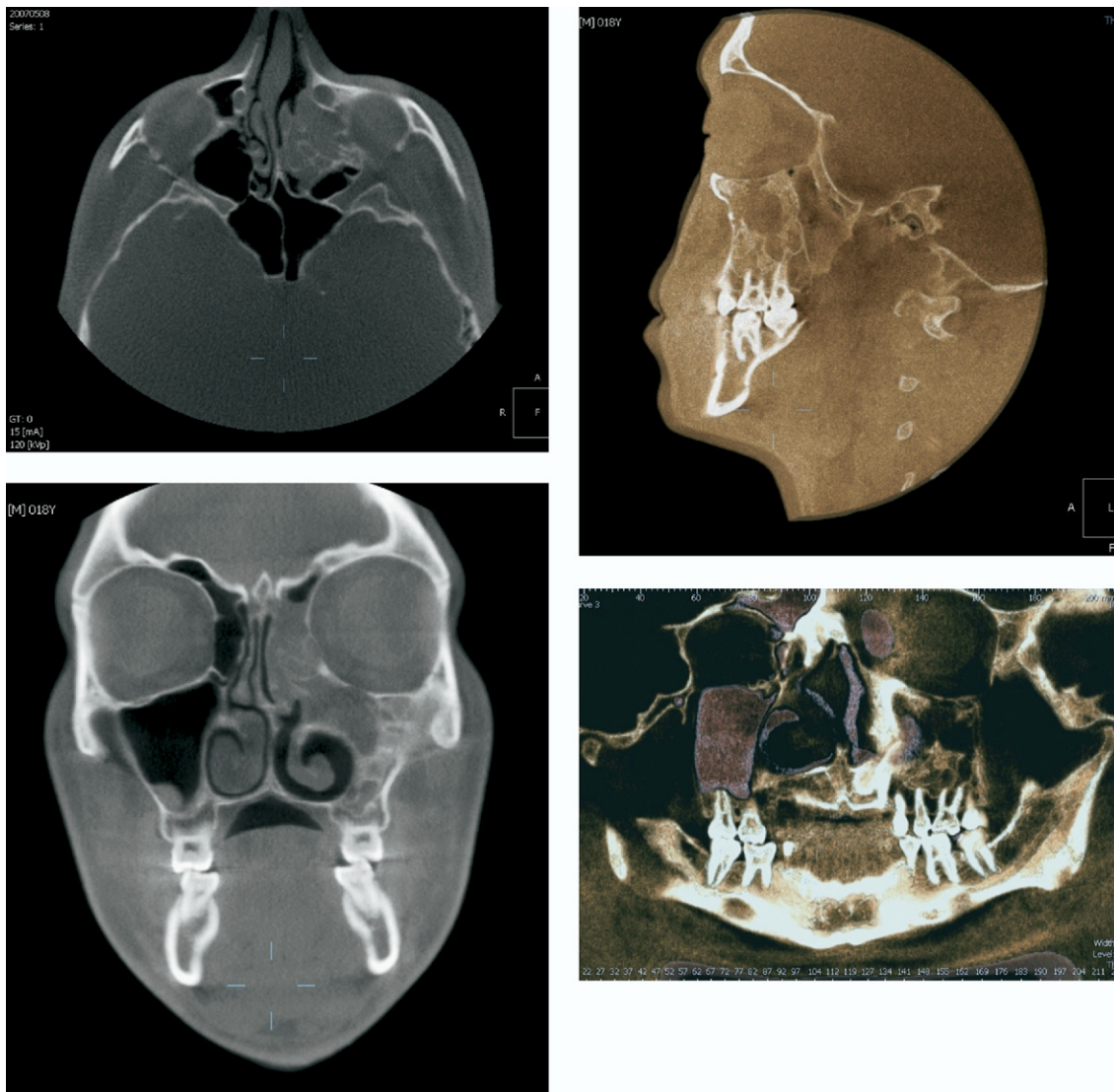
year 2025.<sup>6</sup> The images above in Fig 2 show these lesions.

**Paranasal sinus disease.** Sinus problems due to infections and allergies are ubiquitous throughout North America. While most true paranasal sinus problems can be managed with antibiotics and antihistamines, some sinus problems masquerade as inflammatory changes or infections. In reality, unless one examines these spaces closely and can recognize the radiographic features of more ominous problems like the mucocoele or intrinsic or extrinsic sinus tumors, significant disorders of these sinus spaces will be missed.

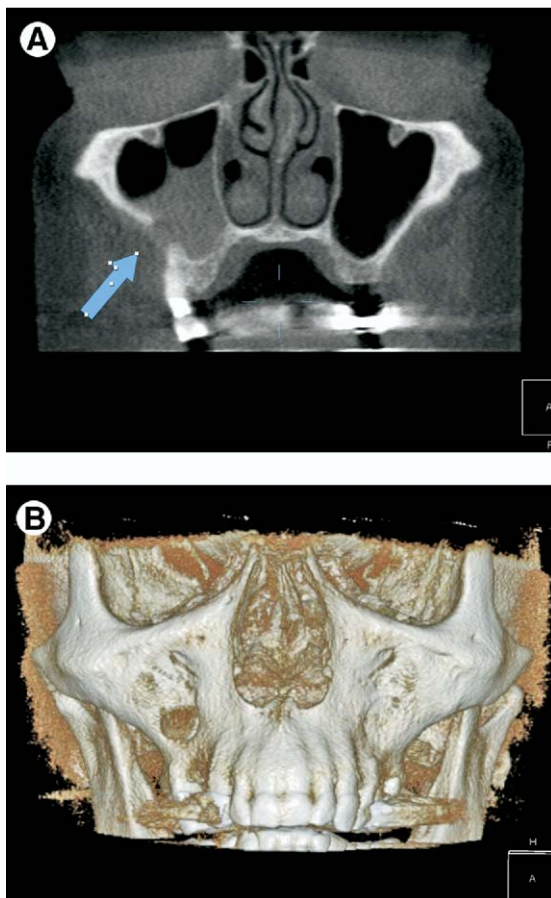
**Mucocoele.** Mucocoeles of the paranasal sinuses are chronic, cystic lesions, lined by respiratory epithelium formed as the result of blockage of the sinus ostium. The secretions produced can produce an expanding mass that, in turn, can erode or remodel sinus walls. While the contents of the mucocoele are usually sterile they can become infected and form a mucopyocoele.

**“Floating tooth.”** The differential diagnosis includes

- a. Localized, severe periodontal bone loss
- b. Langerhan’s cell disease



**Figure 5.** Tumor extending from left maxilla to left superior ethmoid air cell region. (Color version of figure is available online.)



**Figure 6.** (A) Lesion in right antrum with perforation of the facial bone (blue arrow). (B) Three-dimensional color reconstruction of the bony perforation (white arrow). This could also be an opening from a Caldwell-Luc procedure since the mucocoele is quite uncommon in the maxillary sinuses. The diagnosis of this condition was not known at the time of reporting. (Color version of figure is available online.)

c. Lymphoma

d. Various sarcomas (osteo-, chondro-, and fibrosarcoma)

While the majority of localized severe bone loss problems are due to periodontal disease, the differential diagnosis above contains some very significant lesions. Dentists, seeing periodontal disease daily in their practice, can be lulled into making the diagnosis of “bone loss” and possibly miss other subtle changes of the more significant lesions listed.

## The Role of the Oral and Maxillofacial Radiologist (OMFR)

Just as the odontogenic lesions of the dental bases are best interpreted by an oral and maxillofacial pathologist, because of the advanced dental training an oral and maxillofacial radiologist receives, they too are in a better position to review the data sets from CBVT scanners. Medical radiologists are already “overburdened” by the cases produced in the United States, and often the primary read is performed by ex-patriot radiologists living overseas to handle the load of cases. So, for the near future, the oral and maxillofacial radiologist is best suited and available to “read” the data volumes from laboratories and scanner owners such as dentists and dental specialists. Certainly an oral and maxillo-



**Figure 7.** A “floating tooth” in the right maxilla. There was advanced horizontal bone loss in other regions, so the report was of a “clinical impression,” and in this case did not include the differential above. (Color version of figure is available online.)

facial surgeon is also trained to look at conventional CT and MR images, but typically they will not have the time to look at cases referred to their offices if they own scanners. The average, simple case requires 30 to 40 minutes to evaluate the slice data (300-500 slices or more) in each of three planes of section. If the surgeon has 20 to 30 cases per week, this could represent 10 to 25 hours of office time just to sort through patient volumes for potential occult pathology. This does not even account for the analytical reports to be delivered to dentists such as an implant site evaluation. And, remember, the owner of the scanner cannot abrogate this responsibility to the referring dentist. Both clinicians would be held responsible for any significant or reportable finding missed that results in harm to the patient.

### The Current Status of OMFR in the United States

Currently there is enough "radiology talent" in the United States and Canada to report on and manage the cases produced by cone beam owners. There are approximately 140 oral and maxillofacial radiologists (OMFRs), diplomates of the American Board of Oral and Maxillofacial Radiology, and 7 training programs. However, each program offers only between 1 and 4 advanced training positions. Most OMFRs are academically based and read only as a part-time activity. With the growth of CBVT exploding, it will not take long for the volume of cases to exceed the capability of the current "talent pool." More programs in OMFR are needed and more OMFRs and dental school graduates need to consider oral and maxillofacial radiology as a dental profession career choice.

### Questions about the Future of CBVT

Many questions remain to be answered concerning adoption and use(s) of CBVT, qualifications of personnel to perform image acquisition procedures, and licensure of individuals who "read" the scans.

1. How many machine vendors will survive?
2. Who should be allowed to perform the image acquisition?

3. Will it be necessary for all hardware and software to be DICOM compliant?
4. When will that happen?
5. Who should be allowed to perform interpretation of the data volume?
6. Where should they be licensed?
7. How many new OMFR programs/individuals will be necessary to service cone beam owners?
8. When will full Picture Archiving and Communication System/Radiology Information System become available for managing CBVT customers and patient flow?
9. What new software applications will be developed?
10. When will selection criteria for prescribing CBVT be developed?

These are only some of the questions being asked and addressed today in the dental imaging world. Cone beam will not replace intraoral or panoramic imaging techniques for dentistry, but it is clear that the rapid adoption and better clinical decision-making data created by CBVT will ensure its continued use and continual adoption. It is hoped that there will be answers for these questions within the next 5 years of cone beam imaging. (Figure 4 to 7).

### References

1. Holmes SM: i-CAT scanning in the dental office. *Fortress Guardian* 9:2, 2007
2. Dolan NC, Liu K, Criqui MH, Greenland P, Guralnik JM, Chan C, et al: Peripheral artery disease, diabetes and reduced lower extremity functioning. *Diabetes Care* 25: 113-120, 2002
3. Herman WH, Eastman RC: The effects of treatment on the direct costs of diabetes. *Diabetes Care* 21(Suppl 3): C19-C24, 1998
4. Miles DA: Clinical experience with cone beam volumetric imaging: report of findings in 381 cases. *US Dentistry* 1:39-41, 2006
5. Almog DM, Illig KA, Carter LC, Friedlander AH, Brooks SL, Grimes RM: Diagnosis of non-dental conditions. Carotid artery calcifications on panoramic radiographs identify patients at risk for stroke. *NY State Dental J* 70:20-25, 2004
6. US Department of Health and Human Services, Centers for Disease Control and Prevention: National Diabetes Fact Sheet: National Estimates and General Information on Diabetes in the United States. Atlanta, GA, US Department of Health and Human Services, Centers for Disease Control and Prevention, 1997, pp 1-8





# Liabilities and Risks of Using Cone beam Computed Tomography



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Dale A. Miles, BA, DDS, MS, FRCD(C)<sup>b,c</sup>

## KEYWORDS

- Cone beam CT • Standard of care • Medicolegal • Liability • Malpractice
- Licensing • Interpretation

## KEY POINTS

- The use of cone beam computed tomography (CBCT) carries with it medicolegal risks of which the practitioner should be aware. These include licensing and malpractice liability concerns.
- A practitioner who intends to take and/or use CBCT scans should seek advice from his malpractice carrier before doing so.
- All scans should be read by someone competent to interpret them.
- Using the services of an out-of-state radiologist to read scans poses its own set of risks.
- Consultation with a malpractice carrier and dental boards is advisable in this situation.

## INTRODUCTION

As technology such as cone beam computed tomography (CBCT) advances apace in dentistry, clinicians who embrace it should understand the potential liabilities and risks associated with the technology. However, the decision to use or not to use new technologies within a practice or on an individual patient should be based on clinical considerations, not on legal ones. Nevertheless, once a decision has been made, clinicians would be well advised to understand the legal implications of their decision and how they use or do not use the new technology. Although the preceding statements apply to all aspects of dentistry, in this article the focus is on CBCT. The reader should bear in mind that in the United States, laws vary from state to state. Thus, a dentist should always seek the advice of an attorney or malpractice carrier to ascertain the law in his or her own state.

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## TO SCAN OR NOT TO SCAN: THE STANDARD OF CARE

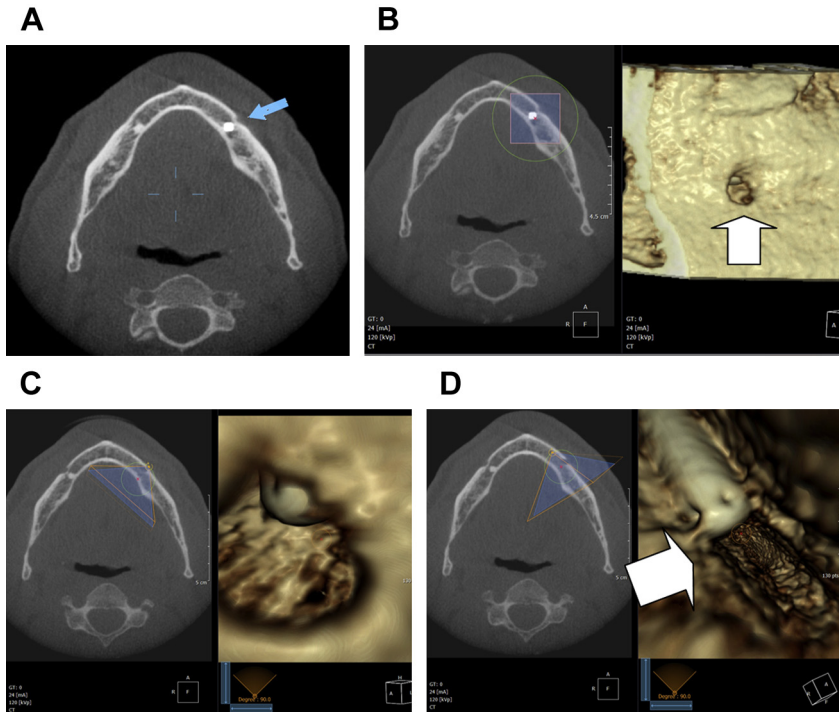
Unlike drugs that must be approved by the Food and Drug Administration for specific indications before they can be put on the market,<sup>1</sup> the same is not true of devices such as CBCT machines. Although all radiographic equipment has to meet federal and state guidelines, it is generally not approved for a particular purpose or indication. For new techniques and technologies for which there are no “standards of care” or long-established or accepted guidelines for their appropriate use, the issue of when and how to use them can be quite problematic for clinicians. A standard of care can be mandated only by a legislature, a court, and a dental board. It is rare, although not unheard of, for the first two to do so. For a case in which a court mandated a standard of care for eye examinations, see *Helling v Carey*.<sup>2</sup>

Dental boards may create a standard of care through their regulations. For example, the Massachusetts Board of Registration in Dentistry specifies what the patient record shall contain.<sup>3</sup> Such a regulation may set a standard of care. There is no private group or association, no matter how esteemed, that is recognized as having the legal authority to establish the standard of care. Neither is there any group that has the authority to mandate a formal process by which a new procedure becomes the standard of care. It is almost universally true that the standard of care is determined by what clinicians actually do in practice. By way of example, in Massachusetts the standard of care is determined by “the degree of care and skill of the average qualified practitioner.”<sup>4</sup> In Washington State, the standard is determined by “a reasonably prudent practitioner.”<sup>5</sup> It is thus up to the profession acting through individual practitioners to decide on the appropriate use of the technology. Professional groups, including speciality organizations, do, however, issue “guidelines for use” or “position papers” on new technologies to help clinicians understand accepted applications, although these do not have the force of law.

In practice, the use of CBCT may be driven in part by vendors of the equipment, who have a pecuniary interest in their sale and use. Although their interest is legitimate, it is not a legitimate interest for practitioners. At the present time, it can be stated that the use of CBCT is well accepted in implant planning (**Fig. 1**) and endodontics (**Fig. 2**), for each of which a position paper exists.<sup>6,7</sup> The use of CBCT is also well accepted to evaluate impacted teeth. A patient with multiple impactions (**Fig. 3**) illustrates this application. CBCT’s use in the evaluation of complex orthodontic and orthognathic cases, such as patients with asymmetries and syndromes, is accepted.<sup>8</sup> Indeed, medical CT was used in such patients long before CBCT became available. Parenthetically, it should be emphasized that to say that the use of CBCT is well accepted is not to imply that its use is mandatory in all or even most cases in any of the dental disciplines.

In the early stages of a new modality, in this case CBCT, a reasonable starting point for a clinician trying to decide when a scan is indicated would be to follow position statements that are endorsed by professional organizations, as well as to ascertain what other dentists in practice are doing. The latter can be done by asking colleagues, by attending conferences, and by reading reputable journals. Unfortunately, in the American system of jurisprudence, a practitioner is far more likely to be sued for not using technology as opposed to being sued for using it. Thus, the inclination to use new technologies, including CBCT, is driven in part by the fear of malpractice.<sup>9</sup>

Another indication that a procedure has become clinically accepted is when third-party payers decide to cover the cost of such care. In medicine, Medicare and Medicaid usually lead the way, with private payers often following their leads on whether to cover a procedure.<sup>10,11</sup> Decisions by third parties, governmental or private,



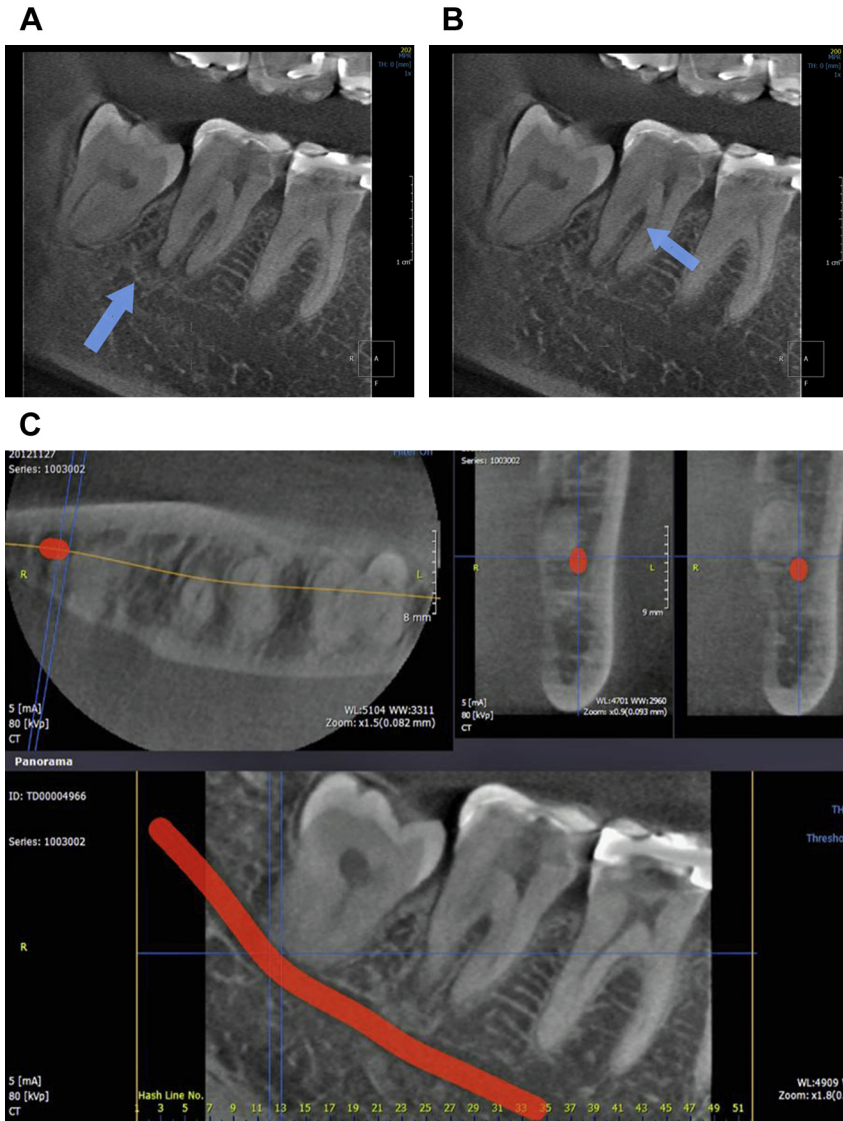
**Fig. 1.** (A) Two-dimensional (2D) grayscale axial view showing an implant near the mental foramen (*blue arrow*). (B) Three-dimensional (3D) color reconstructed view showing a hint of implant immediately adjacent to the inferior alveolar canal before it exits the mental foramen (*white arrow*). (C) Three-dimensional color reconstructed image using a virtual endoscopic tool (OnDemand3D, CyberMed, Irvine, CA) showing a high-resolution image of the implant apparently in the foramen or canal. (D) Using the same virtual endoscopic tool, we discovered the implant in actual contact with the inferior alveolar nerve canal (*white arrow*). In this case, the patient had some parasthesia and the recommendation to the referring clinician was to immediately remove the implant.

are not the final word on whether a procedure is clinically accepted or constitutes the standard of care; that is decided by what the average qualified practitioner does. However, a decision to pay is more meaningful than a decision not to cover a procedure, as the motivation for the latter may be primarily a cost-containment measure. In dentistry, where the use of the word insurance is really misleading,<sup>12</sup> a decision not to cover a procedure commonly involves primarily or exclusively financial considerations for third party payers. Thus, in dentistry, the decision to cover a procedure is much more significant than a decision to deny coverage.

For a comprehensive discussion on how new technologies and procedures may become the standard of care, see the article by Friedland.<sup>13</sup>

## TECHNICAL PARAMETERS

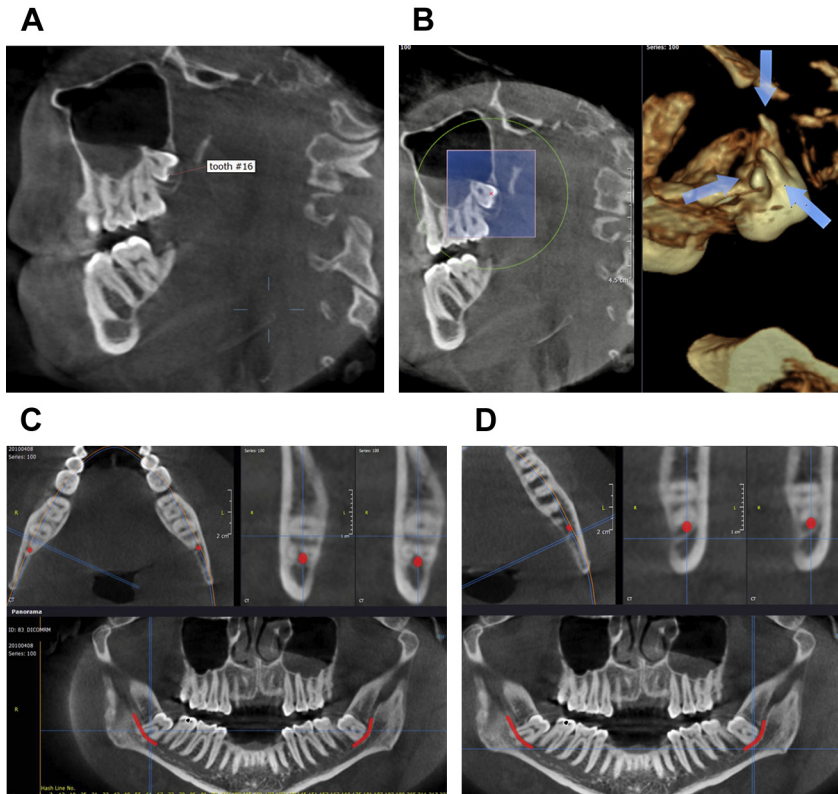
Proper technical parameters are important to obtain a clinically acceptable scan. Improper technical parameters also may lead to liability. These include selecting a low-resolution setting (0.3 mm voxel or higher) for a task requiring high resolution (0.2 mm voxel and lower) and selecting an inappropriate field of view (FOV). The reader



**Fig. 2.** (A) Apical lesion discovered on tooth #31 on acquiring volume for examining impacted tooth #32. This apical lesion was not appreciated on the 2D grayscale periapical radiograph. (B) Small furcation defect or possible lesion of endodontic origin from lateral canal of this tooth. (C) Inferior alveolar nerve (IAN) “painted” in software to reveal that apical lesion on tooth #31 may be irritating the nerve. Tooth #32 is also in contact with the IAN, which is important for presurgical planning information.

should be aware that when it comes to resolution, a higher number means that the resolution is worse, and vice versa. For example, a scan done at a resolution of 0.3 mm voxel has a higher resolution than a scan done at 0.4 mm voxel. Spatial resolution is expressed in line pairs/millimeters or voxel size. For practical purposes, it can be defined as the ability of an imaging modality to differentiate 2 objects, or





**Fig. 3.** (A) At first glance, tooth #16 appears to have fused roots in the 2D reconstructed image. (B) Three-dimensional reconstruction and rotation of the image reveals multiple, divergent, and fine roots, any one of which might be fractured during the surgical removal of the tooth. (C, D) Painting the inferior alveolar nerves shows that it intimately contacts the apices of teeth #17 and #32. As an aid to presurgical planning, possible surgical misadventure, and postoperative sequelae, CBCT is invaluable to help depict for the patient the potential problems with the removal of these impacted teeth.

as the fineness of detail that can be observed in an image. Low spatial resolution techniques will be unable to differentiate between 2 objects that are close together and may be unable to discern a small object, such as a fracture in a tooth. The FOV refers to the physical size of the anatomy that is covered by the exposure, usually selectable from about  $37 \times 50$  mm (typically for a single endodontic procedure) up to as large as  $20 \times 20$  cm (eg, an orthodontic or oral and maxillofacial surgery patient).

Owners and operators of CBCT equipment should be familiar with the technical parameters required for a specific examination. Unfortunately, many dentists who install a machine are not adequately trained to fully understand and take advantage of their machine's capabilities. Common errors include a scan with an FOV that is too large or too small. A larger FOV than is necessary has at least 2 deleterious effects. It results in a less optimal image (the larger the FOV, the greater the scatter and the less detailed the image) and a greater patient dose. Although increased scatter and dose are not likely to result in liability, a wider FOV than is necessary does have medicolegal implications as far as interpretation of the image is concerned, an issue that is discussed later in this article. A too small FOV may preclude the ability to interpret the image

correctly. Some machines also allow the operator to control or select the kilovoltage and milliamperage. Selecting too low a milliamperage setting may result in a poor scan by reducing the number of resultant x-ray photons available, resulting in a less than optimal scan, often with much soft tissue scatter, and thus poor image quality for interpretation. Too high a milliamperage setting will result in increased dose. Understanding these parameters is critical to producing the best diagnostic quality scan.

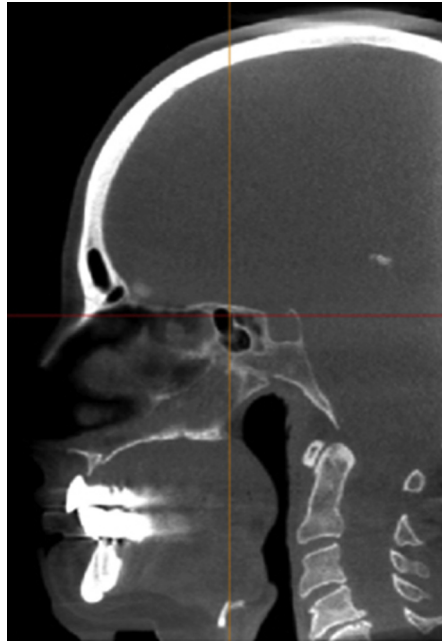
### **Resolution**

When one is looking at very small structures, such as individual canals or fractures of teeth, it stands to reason that a high-resolution image is necessary. In a 2009 article, it was stated that for endodontics the minimally acceptable resolution should not exceed 200  $\mu\text{m}$  (0.2 mm).<sup>14</sup> With current machines capable of much higher resolutions, in the range of 0.07 mm and better, endodontic scans today should be done at or near the highest resolution possible. Should a practitioner do a scan for endodontic purposes at too low a resolution, the information being sought may not be depicted. Such a scan would be inadequate for the purpose for which it was taken and could result in liability for anything missed that would have been visible on a scan done with appropriate resolution. In addition to the resolution selected by the operator, the smaller the scan volume or FOV the better the resolution; thus, endodontic scans should be done with the smallest reasonable FOV.<sup>14</sup>

### **FOV**

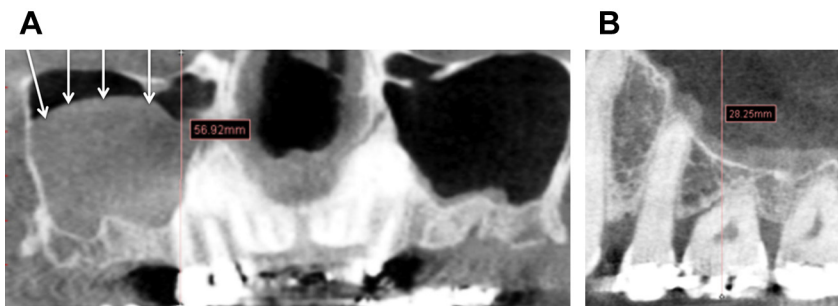
An important consideration for a scan is what to include within the FOV. On the one hand, one wants to keep the FOV as small as possible, both to reduce patient x-ray dose and to improve spatial resolution in the images. On the other hand, the FOV should include a sufficient view of the anatomic area so that one acquires the necessary information. Examples of scans that are underinclusive and overinclusive are common. **Fig. 4** is a sagittal slice of a scan that was done for the purpose of planning mandibular implants. Clearly, anything below the inferior cortex of the mandible and 2 to 3 mm superior to the occlusal plane is superfluous. The potential liability issue that arises is that the dentist is responsible for reading the entire scan.<sup>15</sup> Thus, even though the maxilla and skull were not required in this case, once they are included in the scan, the dentist is responsible for pathology missed in either location.

Too small an FOV carries its own risk. This is seen most commonly in the maxilla. **Fig. 5A** shows a large FOV CBCT scan performed for maxillary implant planning purposes. The panoramic reconstruction shows a large mucous retention cyst in the right maxillary sinus. The diagnosis can be made from the dome-shaped superior aspect of the lesion. Blood, exudates, transudates, thickened mucosa, and other soft tissue in the sinus have a similar opacity on CBCT scans. Thus, one must rely on the shape and distribution of the lesions to differentiate between them.<sup>16</sup> Importantly, when it comes to the shape, it is the superior aspect of the lesion (eg, dome-shaped, straight, meniscus) that is significant and that allows one to distinguish among the various conditions. It follows then that to be able to make this differentiation, one must image the entire sinus, up to the orbital floor, as lesions may fill the entire or almost the entire sinus. If a dentist takes a small FOV scan and sees pathology in the maxillary sinus, but is unable to visualize the superior border of the pathology, then the dentist is obligated to obtain a second scan that includes the entire sinus. This is necessary for 2 reasons. First, the clinician will be not be able to ascertain from the small FOV scan whether the pathology is impinging on the ostium or may do so after surgery such as a sinus augmentation. Second, the clinician will not be able to identify the nature of the pathology.



**Fig. 4.** This scan was done for the purpose of planning mandibular implants. It is an example of an FOV that is much larger than is required. The dentist is responsible for reading the entire scan and not just the region (mandible) related to the reason for taking the scan.

**Fig. 5B** shows a small FOV scan in a different patient from that in **Fig. 5A**. Assume that the same size mucous retention cyst was present in the patient on whom the small FOV scan was taken. From the images, it is readily evident that the superior aspect of the mucous retention cyst would not have been visible on the small FOV scan. In this case, one would have needed to take a second scan, this time a large FOV scan. For this reason, although small FOV scans are adequate when planning mandibular



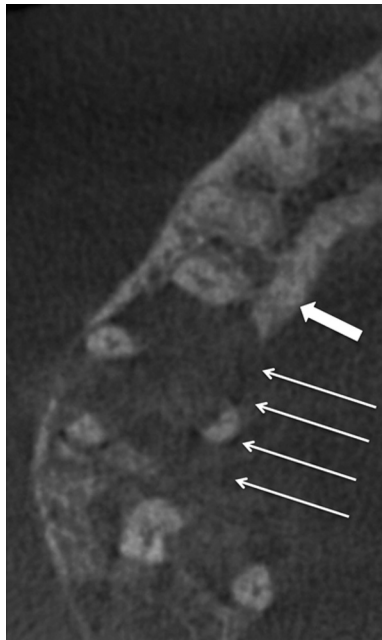
**Fig. 5.** (A) This reconstructed panoramic image shows a large FOV depicting a mucous retention cyst. The superior dome-shaped border (*white arrows*) allows one to make the diagnosis. (B) From this view of a different patient's scan, it is clear that the superior border of a mucous retention cyst that fills or largely fills the maxillary sinus, as it does in (A), would not be visible, making a diagnosis impossible. This shows the importance of doing a large FOV scan in the posterior maxilla.

implants, a larger FOV that encompasses the entire maxillary sinus is preferable in the maxilla.

This principle is based on the fact that sinus pathology is common even in asymptomatic patients. The symptoms of sinusitis may be “subclinical” and manifest only at the next insult, such as an allergen or common rhinovirus. The prevalence of pathologic findings on CBCT scans of asymptomatic patients has been reported to vary from 24.6% to 56.3%.<sup>17–19</sup> Pette and colleagues<sup>20</sup> reported sinus pathology in 61.95% of patients on whom a CBCT scan had been done for implant planning purposes, although Rege and colleagues<sup>21</sup> reported findings in 68.2% of cases of asymptomatic patients. A large FOV does not imply that both sides should be included in a scan, as is seen in [Fig. 5A](#). If surgery is going to be undertaken on only one side, and the CBCT machine allows for imaging only one side while including the entire sinus, then that is preferable.

It is generally true that dentists prefer small FOV scans because they believe that it is not unlike a periapical scan in size and scope and that they are therefore able to read it themselves. This, they believe, limits their liability by excluding anatomy that they are not comfortable interpreting. Although small FOV scans are preferable because they reduce patient dose and improve spatial resolution, the motivation for selecting a small FOV should not be to limit a dentist’s liability. Further, serious pathology may present even on small FOV scans. [Fig. 6](#) shows a cropped axial image of a small FOV scan undertaken for endodontic purposes. The image raised the possibility of a malignant lesion, which was later confirmed on biopsy.

In summary, the anatomy covered by a CBCT scan should be dictated by the patient’s symptoms and the dentist’s findings on clinical examination, and the



**Fig. 6.** This cropped axial image is of a small FOV scan undertaken for endodontic purposes. The *large arrow* points to the palatal cortex. There is destruction of the palatal cortex (*small arrows*). Together with other views (not shown) from this scan, the lesion was identified as being malignant. Biopsy showed it to be an osteogenic sarcoma.



information needed to allow a proper diagnosis or treatment plan to be formulated. The FOV should not be selected in an attempt to avoid liability; that decision may actually increase the risk of liability.

## INTERPRETING CBCT IMAGES

The interpretation of CBCT images remains one of the most vexing problems for practitioners who take their own scans, and potentially among their greatest sources of liability. After all, a missed malignancy is much more likely to result in liability with a big payout than almost anything else a dentist does. Although malignancies are rare compared with typical dental pathology, so that the risk of encountering one and not diagnosing it is small, if the risk does materialize, the consequences are great, most especially for the patient. The damage to the dentist's reputation and especially his or her conscience, and not the financial penalty, may be the greatest casualty.

Among dental school faculty, especially among those who teach radiology, there is currently debate on whether to teach dental students to interpret CBCT scans and, if so, to what extent. Certainly, dentists who graduated before CBCT became widely used probably had minimal or no instruction on CBCT interpretation, so that they are ill equipped to interpret anything more than a small FOV scan and perhaps even then not all of those. For dentists who desire to improve their CBCT interpretive skills, there are courses available. One such course, "Basic User CBCT Course," is offered by oral and maxillofacial radiologists with the American Dental Association (ADA) as the sponsoring organization. Information on this course, which is offered a few times each year, may be found on the Web site of the American Academy of Oral and Maxillofacial Radiology at [aaomr.org](http://aaomr.org) under the "CE Courses" menu, as well as on the ADA Web site by typing "CBCT Course" in the search function field.

Dentists who take their own scans are responsible for reading them. This does not mean that either ethically or legally the dentist has to personally read them, only that he or she bears responsibility for making sure that they are read by a competent individual. This is no different from a dentist who refers out any other procedure that he or she is not competent to perform. Dentists who have their scans taken elsewhere are similarly responsible for having them read. In certain parts of the United States, the services of so-called imaging centers are used by many dentists.<sup>22</sup> In these states, the imaging centers may be owned and operated by nondentists and even by nonmedically trained radiologic technicians. In California, for example, so-called limited permits are issued to nondentists who have training and have passed an examination in the taking of dental images, including CBCT scans.<sup>23</sup> Although well trained in the technical art of taking high-quality images, these otherwise lay individuals are obviously unable to interpret them. In this case, referring dentists have 3 courses of action open to them:

1. Interpret the images themselves.
2. Refer to a radiologist to read them.
3. Use a scan center offering a "reading service" by a radiologist to read the scan.

A dentist who engages his or her own radiologist has more control over ensuring that the radiologist's work meets the standard of care for that specialty. A dentist who relies on an imaging center to engage a radiologist to read scans may not know the radiologist's qualifications. The latter situation could raise liability issues based on the legal concept of negligent referral.<sup>24,25</sup> Although lawsuits brought on the basis of this concept are rare, they do exist and clinicians should be familiar

with the risk, albeit a small one. To be held liable, a clinician “must know or have reason to know that the specialist is incompetent.”<sup>24</sup> This means that the law does not impose an affirmative duty on the clinician to take steps to ascertain the specialist’s competence. Only if the clinician in fact knows or should know that the specialist is incompetent may the dentist be held liable. In the situation in which the dentist relies on an imaging center, especially one owned by a layperson, to select a reading radiologist, things may be a little grayer. After all, is it reasonable for a dentist to rely on a lay individual to select a competent practitioner, in this case a radiologist? This is all the more true when one considers the issue in the context of licensing as well, a matter discussed in the section “The reading of scans over the Web,” later in this article.

If a dentist owns and/or operates a CBCT machine and takes a scan for a patient other than his or her own, the question arises whether the dentist taking the scan is responsible for reading it or whether it is the responsibility of the referring dentist. In practice, there are medical and dental practices and facilities, including hospital radiology departments, that take dental scans, most commonly for implant planning purposes. Many of these facilities do not read the scans, but instead have a disclaimer. An example of such a disclaimer is one from the Massachusetts General Hospital, which states: “These images were NOT reviewed by a Mass General radiologist for diagnostic purposes, and NO radiological review, report, or professional bill was generated. These images are intended for review by dental care professionals to aid in dental implant or extraction surgical planning. Mass General Imaging makes no diagnostic claims regarding these images. If there are concerns regarding pathology and a radiological consult is desired, please contact ...” As long as it is made clear to the referring dentist, and preferably the patient as well, that only the technical service of taking the scan is being offered, that should preclude any liability on the part of the dentist taking the scan. However, the dentist who *ordered* the scan will be responsible for reading it or having it read by a competent practitioner.

Although a disclaimer is likely to insulate from liability an entity or individual who is just taking the scan, in practice many and perhaps most such entities or individuals require the ordering dentist to obtain a reading from them. They do so to avoid any possibility of being sued, based on the adage that “the aim is not to win a lawsuit, but to prevent one.”

## WHAT NEEDS TO BE READ

Whoever reads the scan is responsible for reading *all* of it, not only the anatomic region for which the scan was taken. This standard is no different from that for any other image taken. A dentist cannot read only part of a cephalogram or panoramic image. For example, in orthodontics, a dentist is responsible not only for that part of the image pertinent to an orthodontic analysis, but for anything that appears anywhere on the image.<sup>26,27</sup> An editorial in the orthodontic literature bears testimony to the fact that this is the accepted standard within the profession.<sup>28</sup>

## THE READING OF SCANS OVER THE WEB

With current technology, it is easy for a scan to be read anywhere that high-speed Internet access is available. Unfortunately, although technology has advanced to make this possible, dental licensing laws are strewn with pitfalls of which the dentist should be aware. Because there is no national license in either dentistry or medicine, practitioners are licensed by state. For licensing purposes, the primary considerations

are where the radiologist who is reading the scan is located and where he or she needs to be and is licensed.

For most of history it was possible for a practitioner to examine a patient only if both were present at the same place and time. This gave rise to the rule is that "It is the location of the patient that defines where the care has been delivered and the jurisdiction of applicable regulations."<sup>29</sup> Although the issue has become more pressing with the advent of the Internet, questions of licensing arose before that. For example, a radiograph could be sent by mail to an out-of-state radiologist for interpretation. A biopsy specimen could be sent out of state for processing and to be read by a pathologist. However, the process was cumbersome and slow, and incidence of this was so low that boards of registration in dentistry and medicine did not address the issue. Given the ease with which images today can be sent over the Internet and be read anywhere, it has become commonplace for practitioners, either themselves or through reliance on imaging centers, to have scans read by radiologists who do not reside in the same state as the dentist. Thus, the question arises "where must the radiologist be licensed, in the state where the dentist practices, in the state where the radiologist practices, or even in both?" Because the purpose of licensing laws is to protect the health and welfare of the citizens of a state,<sup>30</sup> the most logical conclusion is that a radiologist reading scans for a dentist located in state A needs to be licensed in state A and only in state A. Even if the radiologist is located in state B, he or she should not be required to be licensed there if he or she is not reading scans for dentists located in state B; after all, state B has no interest in protecting its citizens from the radiologist if he or she is not affecting their care. Although some medical boards have considered the matter and even issued guidelines or regulations,<sup>31</sup> few dental boards, if any, have provided explicit guidelines concerning this matter. Further, the constitutional standard that a state has to meet to justify requiring licensure is extremely low,<sup>32</sup> and it is almost certain that in the preceding example state B would be well within its right to require the radiologist to be licensed there. If the radiologist fails to obtain a license when a state has deemed it necessary to do so, the radiologist could be charged with practicing without a license. Referral to a radiologist who is not licensed in the state in which the dentist is located may make the dentist vulnerable to disciplinary action by the dental board and may also make the dentist guilty of the crime of aiding and abetting the unlicensed practice of dentistry.<sup>33</sup> Thus, a dentist who has scans read by an out-of-state radiologist should confirm that the radiologist is appropriately licensed. Both the board of the state in which the dentist is located, as well as the state in which the radiologist is located should be consulted.

The issue of licensing ties-in with potential liability for negligent referral. If a dentist has scans read by a radiologist not licensed in the dentist's state, this may increase the chances of a suit based on negligent referral. This is true whether the dentist contracts directly with the radiologist or uses the radiologist's services through an imaging center. Because of the rarity of negligent referral lawsuits, the possibility of this occurring should not be overemphasized. However, the chances may be higher under the circumstances discussed here. It behooves dentists to know the credentials of the radiologists they use.

There is one very practical consideration that a dentist who uses the services of an out-of-state radiologist should bear in mind. Assume that the radiologist makes a misdiagnosis and that both the radiologist and the dentist are sued. Imagine the reaction of a jury to the plaintiff's attorney's question directed to the radiologist from state B, "are you licensed to practice in state A (where the dentist practices and the patient lives)?" and the radiologist responds "no." That may poison the well enough for the jury to find against the dentist, other evidence notwithstanding.

To overcome the limitations imposed by licensing requirements, dentists have sought to couch the referral of scans to be read as merely the seeking of a second opinion. The second opinion is a long-used and well-respected tool in the health care professions. Indeed, some states explicitly recognize it and do not require the out-of-state practitioner to be licensed when giving a second opinion. Massachusetts recognizes it by statute, stating that a Massachusetts license is not required by “a physician or surgeon resident in another state who is a legal practitioner therein, when in actual consultation with a legal practitioner of the commonwealth” he provides an opinion.<sup>34</sup> Note that the “outside” physician must actually consult with the in-state physician. The licensing exception also applies only when such consultation is made on a one-time or occasional basis. If a physician routinely consults a physician who is not licensed in Massachusetts, the licensing exception does not apply. Hence, the “second opinion” argument will not fly when every scan or most scans are sent out to be read, and when the dentist has not read the scan and made at least an initial diagnosis.

### ATTEMPTS TO LIMIT LIABILITY

Attempts to limit malpractice liability are not restricted to CBCT, nor are they new, but they have gained new traction since the introduction of CBCT, and especially as dentists purchased machines and started taking their own scans rather than referring patients to radiology facilities. Dentists untrained in the interpretation of CBCT scans became concerned about liability in the event they misinterpreted a scan. One course of action that has been suggested is to ask a patient to sign a waiver of liability; that is, in effect to require a patient to give up the right to sue for negligence. Waivers of liability have no legal effect and courts will ignore them. Most jurisdictions that have considered the matter have held that physicians and hospitals cannot require patients to waive their rights to recover damages for negligence.<sup>35,36</sup>

Because requiring a patient to waive his or her right to sue will not pass muster, practitioners have considered another tack. This one involves letting the patient choose whether to have the scan read. The thinking here is that by leaving the decision up to the patient, there should be no liability on the part of the dentist for any misdiagnosis. This tactic also will not work. The choices offered to patients to allow them to make informed decisions are limited by the bounds of the accepted standard of care. For example, no dentist would permit a patient to agree to a restoration on a tooth that clearly requires endodontic therapy first, because such treatment would be below the standard of care. Similarly, not having a CT scan read is below the standard of care.

Some health care practitioners and organizations have sought to use a contract to limit at least the noneconomic damages that a patient may recover. It is unclear whether such private agreements will be enforced by courts. Of course, if a state legislature has enacted such limits, then that law will govern any malpractice award. Florida is an example of a state that has capped noneconomic damages.<sup>37</sup> Whether a state law mandating limits on noneconomic damages will withstand scrutiny by a court depends in large part on a state’s constitution and it is likely that such a law will ultimately be challenged in a state’s highest court.

Although it does not limit the amount of damages that a patient may collect, arbitration allows for much quicker and simpler resolution of a case. The Federal Arbitration Act<sup>38</sup> encourages the settlement of disputes by arbitration and preempts state law.<sup>39</sup> A dentist could thus include a compulsory arbitration clause in a contract with a patient. It is highly likely that a court will enforce such an arbitration clause, provided it is not unreasonable.



## MALPRACTICE INSURANCE

In addition to making sure that the radiologist is appropriately licensed, the dentist should inquire about the radiologist's malpractice coverage. This applies not only to the dollar amount of coverage, but also to whether there are any limitations to coverage. For example, is there a clause that limits coverage only to where the radiologist is lawfully licensed to practice? If so, and the radiologist is reading scans for a dentist in state A, but is not licensed there, then the insurance carrier may deny coverage. Thus, in addition to checking with state licensing boards on where licensure is required, the dentist should check with the radiologist's malpractice carrier on any limitations in coverage, or ask the radiologist to provide verifiable information. If, in the case of a suit, a radiologist's malpractice carrier denies coverage, this could conceivably leave the dentist being the only "deep pocket," with the patient then suing the dentist. This does not mean that the patient will prevail in a suit against the dentist if the dentist was not otherwise negligent but, to quote the adage again, "the aim is not to win a lawsuit, but to prevent one." All the extra work of checking into a radiologist's licensure requirements and malpractice coverage may seem overly burdensome, but it is the price we pay for a fractured system of licensure, there being no national license in the United States.

If a dentist owns a CBCT machine and takes scans not only for his or her own patients, but also for those referred from outside, the dentist may find that in the latter situation he or she lacks malpractice coverage in the event of a lawsuit. Some malpractice carriers have explicit limitations and will defend a dentist for CBCT-related diagnostic issues only if the suit is brought by one of the dentist's own patients. If a patient who was referred from outside solely for a CBCT scan and brings a lawsuit for a misdiagnosis, then malpractice coverage is denied. A dentist may be able to purchase a rider from the malpractice carrier to cover patients of this type. In practice, denial of malpractice coverage usually means that a patient (plaintiff) is less likely to sue, as there is no insurance money to go after. However, denial of coverage is not a bar to a patient bringing a suit; the patient may well decide that the dentist has sufficient personal assets from which to pay a judgment such that the patient proceeds with a suit.

## SUMMARY

This article addresses the principal medicolegal issues facing owners and users of CBCT today. Dentists who operate CBCT units would be well advised to speak with their malpractice carrier before purchasing a machine, as coverage may differ depending on circumstances. Dentists using an out-of-state radiologist to read scans should verify that the radiologist has the appropriate licenses as well as malpractice coverage. Any contract that a dentist wishes to use between the dentist and patients should be vetted by an attorney and preferably by the malpractice carrier as well.

## REFERENCES

1. Federal Food, Drug, and Cosmetic Act. 21 United States Code, Ch. 9.
2. *Helling v Carey*, 83 Wash. 2D 514, 519 P. 2d 981 (1974).
3. 234 CMR §5.15.
4. *Brune v Belinkoff*, 354 Mass. 102, 235 N.E.2d 793 (1968).
5. *Harris v Groth*, 99 Wash. 2D 438, 663 P.2d 113 (1983).
6. Tyndall DA, Price JB, Tetradis S, et al. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology

- in dental implantology with emphasis on cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2012;113:817–26.
7. American Association of Endodontists, American Academy of Oral and Maxillofacial Radiology. Use of cone-beam computed tomography in endodontics. Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;111(2):234–7. Available at: [http://c.ymcdn.com/sites/www.aaomr.org/resource/resmgr/Docs/AAOMR-AAE\\_postition\\_paper\\_CB.pdf](http://c.ymcdn.com/sites/www.aaomr.org/resource/resmgr/Docs/AAOMR-AAE_postition_paper_CB.pdf). Accessed April 28, 2014.
  8. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontic treatment. Joint position statement by the American Academy of Oral and Maxillofacial Radiology American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2013;116(2):238–57.
  9. Pollack A. Medical technology 'arms race' adds billions to the nation's bills. *N Y Times Web* 1991;29(A1):B8. Available at: <http://www.nytimes.com/1991/04/29/us/medical-technology-arms-race-adds-billions-to-the-nation-s-bills.html?pagewanted=all&src=pm>. Accessed April 28, 2014.
  10. Available at: [http://www.prgweb.com/resources/key\\_elements\\_of\\_reimbursement.php](http://www.prgweb.com/resources/key_elements_of_reimbursement.php). Accessed April 28, 2014.
  11. Available at: [http://www.emersonconsultants.com/\\_assets/document/Fundamentals\\_of\\_Reimbursement\\_Chapter.pdf](http://www.emersonconsultants.com/_assets/document/Fundamentals_of_Reimbursement_Chapter.pdf). Accessed April 28, 2014.
  12. Weiss HS, Hecht L, Friedland B. Health insurance coverage for oral diseases. Toward a more sophisticated model. *J Leg Med* 2003;4(2):175–98.
  13. Friedland B. To scan or not to scan: medico-legal implications in cone beam computed tomography. In: Kapila S, editor. *Orthodontics: Indications, Insights and Innovations*. Ames (IA): Wiley, in press.
  14. Scarfe WC, Levin MD, Gane D, et al. Use of cone beam computed tomography in endodontics. *Int J Dent* 2009;2009:634567. Available at: <http://dx.doi.org/10.1155/2009/634567>. Accessed April 28, 2014.
  15. Friedland B. Clinical radiologic issues in orthodontic practice. *Semin Orthod* 1998;4(1):64–78.
  16. Ruprecht A, Lam EW. Paranasal sinuses. In: White SC, Pharoah MJ, editors. *Oral radiology: principles and interpretation*. 6th edition. St Louis (MO): Mosby; 2009. p. 510.
  17. Ritter L, Lutz J, Neugebauer J, et al. Prevalence of pathologic findings in the maxillary sinus in cone-beam computerized tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;111(5):634–40.
  18. Pazera P, Bornstein MM, Pazera A, et al. Incidental maxillary sinus findings in orthodontic patients: a radiographic analysis using cone-beam computed tomography (CBCT). *Orthod Craniofac Res* 2011;14(1):17–24.
  19. Cha JY, Mah J, Sinclair P. Incidental findings in the maxillofacial area with 3-dimensional conebeam imaging. *Am J Orthod Dentofacial Orthop* 2007;132(1):7–14.
  20. Pette GA, Norkin FJ, Ganeles J, et al. Incidental findings from a retrospective study of 318 cone beam computed tomography consultation reports. *Int J Oral Maxillofac Implants* 2012;27:595–603.
  21. Rege IC, Sousa TO, Leles CR, et al. Occurrence of maxillary sinus abnormalities detected by cone beam CT in asymptomatic patients. *BMC Oral Health* 2012;12:30. Available at: <http://www.biomedcentral.com/1472-6831/12/30> <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3511216/>. Accessed April 28, 2014.

22. American Association of Dental Radiographic Technicians. Available at: <http://www.aadmrt.com>.
23. California Health and Safety Code §§ 106955-107111. The appropriate sections can be viewed at: <http://law.justia.com/california/codes/hsc/106955-107111.html>. Accessed April 28, 2014.
24. Estate of Tranor v Bloomsburg Hosp., 60 F. Supp. 2d 412, 416 (M.D. Pa. 1999).
25. Datiz v Shoob, 71 N.Y.2d 867, 868 (1988).
26. Alkofide E. Pituitary adenoma: a cephalometric finding. *Am J Orthod Dentofacial Orthop* 2001;120(5):559–62.
27. Friedland B, Meazzini MC. Incidental finding of an enlarged sella turcica on a lateral cephalogram. *Am J Orthod Dentofacial Orthop* 1996;110(5):508–12.
28. Turpin DL. Befriend your oral and maxillofacial radiologist. *Am J Orthod Dentofacial Orthop* 2007;131:697.
29. Statements on Telemedicine - Board for Professional Medical Conduct, New York Department of Health, July 2005. Available at: <http://www.health.state.ny.us/nysdoh/opmc/telemedicine.htm#notes>. Accessed April 28, 2014.
30. U.S. Department of Commerce Telemedicine Report to Congress, January 31 1997. Available at: <http://www.ntia.doc.gov/reports/telemed/index.htm>. Accessed April 28, 2014.
31. Available at: [http://www.fsmb.org/pdf/grpol\\_telemedicine\\_licensure.pdf](http://www.fsmb.org/pdf/grpol_telemedicine_licensure.pdf). Accessed April 28, 2014.
32. Fogland v Board of Registration in Medicine 357 Mass 624259 NE2d 780 (1970).
33. Texas Occupations Code, Title 3, Subtitle D, Chapter 251; California Business and Professions Code §2264.
34. Massachusetts General Laws Chapter 112: Section 7.
35. Dahl D. Doctors' 'no sue' contracts spark debate. *Lawyers USA*. May 21, 2007.
36. Ginsburg WH, Kahn SJ, Thornhill MC, et al. Contractual Revisions to Medical Malpractice Liability. *Law Contemp Probl* 1986;49(2):253–64.
37. Florida Statutes Title XLV Chapter 766. Available at: <http://www.flsenate.gov/laws/statutes/2011/766.118>. Accessed April 28, 2014.
38. 9 U.S.C. § 1 et seq.
39. Sacopulos M, Segal JJ. Limiting exposure to medical malpractice claims and defamatory cyber postings via patient contracts. *Clin Orthop Relat Res* 2009; 467(2):427–33.







## **"Look Who's Making Radiology Experts Out Of Specialists"**

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### **Part I - The Problems**

#### **1. Rapid Adoption of Specialized Technology**

There is no doubt that cone beam computed tomography (CBCT) has captured the attention of the dental profession unlike any other technology introduced to us in the past 50 years. Because this imaging modality has so many applications crossing all of the disciplines and specialties of dentistry, clinicians have adopted CBCT in great numbers. One of the distinct advantages is that you don't have to own the technology in order to use the data from to make better clinical decisions. This is a good thing. However, in order to maximize the market penetration; that is, sell more machines, manufacturers have taken it upon themselves to make their early adopters radiologists. This is a bad thing.

Until 1999, all dentists were their own radiologists. After more than 50 years of applying and petitioning the American Dental Association, the American Academy of Oral and Maxillofacial Radiology was granted specialty status by the House of delegates to become dentistry's ninth specialty. To this day, more than a decade later, a significant number of my colleagues still do not know that oral and maxillofacial radiology is a specialty! This is another bad thing.

So how does the manufacturer leverage their position into the marketplace? They do it by marketing those who purchase their machines not only as educators but also as radiologists. Dentists who attend courses sponsored by manufacturers and their users come to believe that that particular clinician is a specialist in radiology. This is rarely the case. To be fair, some manufacturers hold multidisciplinary educational programs which include an Oral and Maxillofacial radiologist, commonly to answer those questions that the purchaser of the machine could not.

Repeating my earlier statement, dentists have had to be their own radiologists since Roentgen discovered the x-ray. Today, however, that is not the case. What disturbs me most about this trend is that many purported CBCT programs are being presented around the country by people who understand how to apply this technology to their specific diagnostic task yet have very little understanding of the principles of CBCT, let alone knowledge of the anatomy in three planes of section and knowledge of the more significant findings that they will encounter in their volumes. This trend is creating significant risk to both the users and the owners that CBCT, expanding the liability possibilities for many surgical procedures that dentists perform. It is not apparent to my colleagues who claim to me that "there is no case law concerning CBCT" but the reason for this is that almost all claims to date have been settled out of court<sup>1</sup>. What clinician in his right mind would want to go to court, lose the case, surrender his or her license and have that added to the national database? Of course the cases are settled long before they ever have a chance to go to the courts.

## **2. Manufacturer's Responsibilities**

To be fair to my manufacturing friends, this type of "viral marketing" is very effective, and I too would employ it to expand the company's influence and sell product. However, to paraphrase a well-known pundit on a national television program "is this fair and balanced"? Manufacturers have the responsibility to educate and even train their clientele. This is especially true if the technology is so new and novel that the dentist have trouble locating the traditional academically-based education. This is always true when the technology precedes the education, which is almost all the time. Educators in dental schools rarely have the budgets to be the early adopters of these technologies. So, in the case of cone beam imaging many machines have been sold by manufacturers without a clear understanding of the potential liabilities to dentists with even less understanding of the potential liabilities. This is not appropriate.

## **3. Dentists as their Own Radiologists**

In addition to the problem of rapidly expanding technology - in the hands of clinicians who have limited understanding of the technology, limited knowledge of the potential liabilities, but who appreciate and understand the usefulness of the technology - we have the problem of the early adopters who are not radiologists educating dentists about radiology. I understand that most of these clinicians, commonly specialists, have an excellent understanding of the utility of CBCT

for their specific application and are able to communicate this to their dental colleagues. However their overall understanding of CBCT is limited in nature areas such as:

- the principles
- the radiation risks
- applications outside of their specialty field
- occult pathology
- multiplanar anatomy
- potential liability

#### **4. Drinking the "Kool-Aid"**

To make matters even worse, manufacturers tend to adopt or create a stable of individuals who use only their technology and thus have been "brainwashed "into believing that that particular technology is the best. Again, to be fair, even educators who have adopted or purchased CBCT in their institutions have usually at least done their due diligence to determine the appropriate technology in terms of need, applications, budget and support before making their purchases. Unfortunately this type of due diligence does not often happen in the "real world ". In many cases the decision to purchase has been made because "my buddy has one of those machines "or is due to an onslaught of advertising and aggressive marketing to which the clinician has been subjected. With this kind of pressure, or lack of due diligence, dentists tend to become "Kool-Aid drinkers ". And, many dentists do not have the time or inclination to actually research the various machines, their own personal applications, patient flow, return on investment and most importantly the machine parameters to dictate whether or not the image data will be the best and the most appropriate for their needs. It's sad but we all know it's true.

#### **5. Specialists as Radiologists**

Backing up to my observation about specialist colleagues using CBCT educating dentists, let me clarify the point I'm trying to make. First, this is not all about me or my specialty.

*I would never consider trying to educate my dentist colleague about crown preparation, implant placement, optimal third molar extraction procedure, endodontic procedures, management of sleep disorders, orthodontic assessment or any other specialized dental procedure for which I was not trained as a specialist.*

Why then, do the manufacturers think that their specialist users can adequately educate my dentist colleagues in radiographic procedures and interpretation of CBCT data sets. And more importantly, why do some of my specialist dental colleagues assume they can take on the role

of the oral and maxillofacial radiologist. Clearly, in my experience, some do not. They "render unto Caesar, that which is Caesar's ". However, some do, in fact try to educate our dentist colleagues about things that were not in their specialty training.

In co-chairing the committee to create the "Joint Position Statement of the American Association of Endodontics and the American Academy of Oral and Maxillofacial Radiology" on the "Use of Cone-Beam Computed Tomography in Endodontics", published in February 2011 in both the Journal of Endodontics<sup>2</sup> and On the AAOMR website ([www.aaomr.org](http://www.aaomr.org))<sup>3</sup>, with Dr. Marty Levin, an endodontist, it became very clear to all panel members that they knew very little about each other's specialty. It was necessary to have input from all panel members both in oral and maxillofacial radiology and in endodontics in order to effectively create the document. The AAOMR has created additional committees to co-sponsor the development of similar guidelines for use of CBCT in implantology, TMJ assessment and other specialty areas. Until such documents are published, manufacturers should be very careful about trying to educate dentists about this technology. The day of the paradigm "Here's how I do it in my practice" are long gone if not extinct. Manufacturers still perpetuate this paradigm. Dentists and dental specialists need to consider the source of the "expert" when considering a substantial shift in their practice such as cone beam imaging. There are very few experts in this area, and all of them are probably in the specialty of oral and maxillofacial radiology. Dentists adopting this technology ought to seek out higher-level CE courses and content that are given by the real specialists in the discipline of radiology.

## **Part II - The Solution(s)?**

Dr. Miles is working on this now, stay tuned...



## References

1. Personal communication, American Academy of Legal Medicine meeting, Orlando, FL March 5, 2010.
2. AAE and AAOMR Joint Position Statement; [www.aae.org](http://www.aae.org), 2010.
3. <http://www.aaomr.org/?page=AAOMRAAE>

## Biosketch

Dr. Miles is a diplomate of the American Board of Oral and Maxillofacial Radiology and the American Board of Oral Medicine. He has authored over 130 peer-reviewed articles and 6 textbooks, including the best selling, 2nd edition atlas on **Cone Beam CT, Color Atlas of Cone Beam CT for Dental Applications** published by Quintessence Publishing. Dr. Miles has a web site for teaching dentists and auxiliaries about digital and cone beam imaging at [www.learndigital.net](http://www.learndigital.net) and a social network television channel called [www.interaactiveimagingtv.com](http://www.interaactiveimagingtv.com) on radiographic topics.

Dr. Miles is in full-time practice of Oral and Maxillofacial Radiology in Fountain Hills, Arizona. He is the President and CEO of **Cone Beam Radiographic Services, LLC.**, a CBCT reporting service for dentists and dental specialists and President of **EasyRiter, LLC**, which produces a simple CBCT report generating software for the profession.



# Reporting Findings in the Cone Beam Computed Tomography Volume



Dale A. Miles, BA, DDS, MS, FRCD(C)<sup>a,\*</sup>, Robert A. Danforth, DDS<sup>b</sup>

## KEYWORDS

- Cone beam computed tomography • CBCT • Diagnostic • Reporting • Liability
- Interpretation

## KEY POINTS

- It is the responsibility of health care providers to acquire information data from patients to best determine the health status of patients and if treatment is indicated and to provide a basis for informed patient consent.
- The use of CBCT for dental treatment planning poses a situation in which the additional data in the acquired image volume that are outside of the scope of the primary dental concern could detect systemic conditions that possibly have a direct influence on the overall health and longevity of a patient.
- Patients can make informed decisions about their health or dental care and treatment. The CBCT report becomes a component of the informed consent standard of care.
- Who provides the report may not be as important as whether or not a report is actually performed.
- The quality, accuracy, and use of a report are subject to medicolegal scrutiny, and knowledge of such issues determine whether or not a primary provider or a secondary radiology reader evaluates the image data and issues the final report.

## INTRODUCTION

As in any disruptive technology introduced to a profession, the education lags far behind the technological advance. This is especially true of cone beam imaging. Dentists and dental professionals are quick to grasp the advantages and applications of using cone beam technology but, once adopted, often make the following statements:

*These images are great, but what am I looking at? and*

*Where can I get more information on interpreting the scan?*

Unfortunately, there is no easy answer and no quick way for dentists to re-educate themselves. Understanding CBCT takes time and effort and even some guidance.

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Manufacturers, also quick to understand the popularity of this technology, often fail to provide even the basic education that is necessary so that clinicians do not inadvertently cause harm to patients. Reporting the findings in a CBCT volume is probably the most essential process in the total diagnostic evaluation of a patient, even if it is something as simple as implant planning. Dentists and dental specialists must not be caught in the trap of only looking at the data they are interested in, such as an impacted tooth or implant site evaluation or characterization of some pathologic entity that they found in another radiograph. They must examine all the data in the scan and must do so in a systematic and somewhat regimented fashion.

This article is designed to help clinicians understand the process and expose them to the methodology the authors use and a software tool the authors developed to help dentists completely examine and report all findings in a scan and take the appropriate next steps when the findings dictate additional action, such as referral to a dental specialist or a colleague in the medical profession. This methodical, diagnostic approach is for precise communication with the referring clientele. When the authors examine and report findings in a 3-D scan, they are looking for occult pathology, that is, anything that might have an impact on a patient's health that the dentist needs to know about and sometimes takes action on.<sup>1,2</sup> The authors cannot afford to miss an important finding or fail to communicate these findings to referring clinicians. For those individuals to examine their own data, this is also true. No clinician would be in trouble for misdiagnosing a condition or problem, but that same clinician is definitely placing himself or herself at risk for not examining the volume for these occult findings. The authors support each of the areas of discussion with cases from their files to illustrate the common and not so common findings discovered in cone beam scans and know this will be helpful to all dentists.

## SYSTEMATIC REVIEW OF IMAGE DATABASE

- A. Confounds: axial sections, smaller field-of-view (FOV) confusion, and anatomy outside the dentists' comfort zone
- B. Suggested method of review

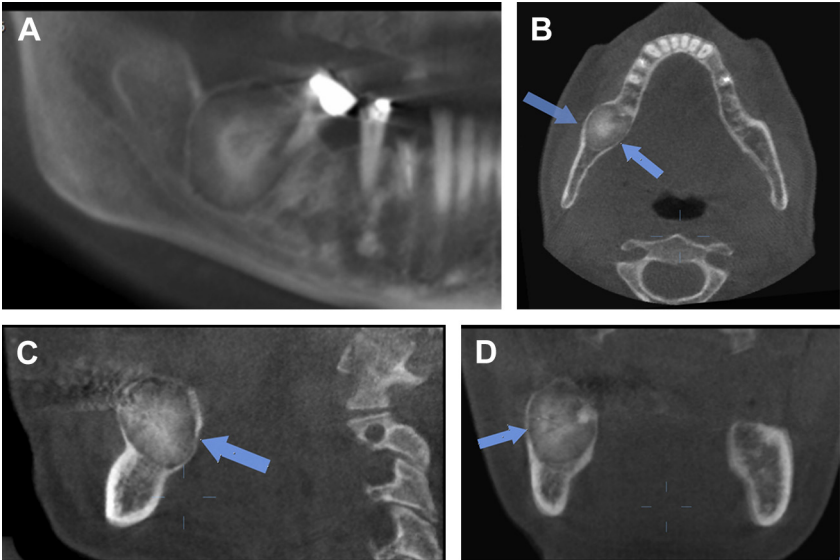
### *Confounds—Some of the Obstacles to Overcome When Examining the Volume*

Most dentists carefully and systematically examine bitewings for interproximal carious lesions; periapical radiographs for signs of bone loss or apical problems; or panoramic images for dental, temporomandibular joint (TMJ), and sinus problems. Through training and clinical experience, they develop their own approaches for a systematic review of the radiographic images. All these images that they were taught to look at, however, are oriented in a sagittal anatomic plane of section. That is, all these images of a patient are looked at from the side. Cone beam data sets significantly alter this paradigm. The coronal and axial anatomic planes of section can also be viewed. Although the coronal plane is understandable, the axial plane of section is a significant departure from the dental paradigm. **Fig. 1** demonstrates a finding in the 3 planes of section.

In addition to the confound of these new planes of orientation, dentists were also informed by the manufacturers that a smaller FOV represented less diagnostic responsibility. Unfortunately, although this is true in most cases, an axial image from a limited field cone beam machine, such as the unilateral capture of the TMJ condyle, when seen in a axial orientation, is confusing. **Fig. 2** illustrates this point.

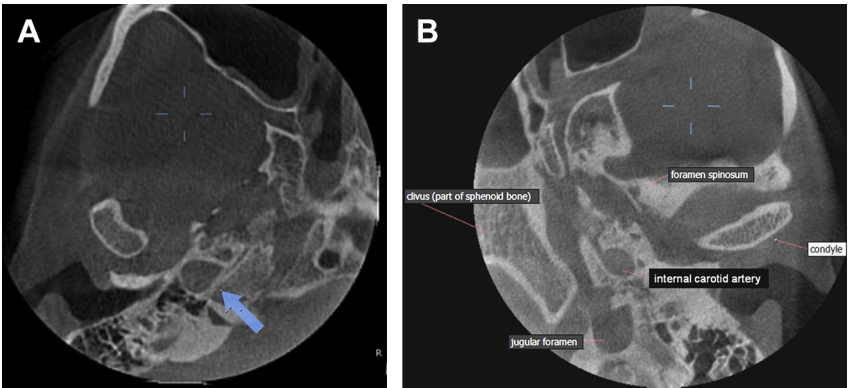
Another obstacle dentists must overcome is educating themselves to look beyond the dental bases to anatomic regions with which they are less familiar. These include





**Fig. 1.** (A) Right side of panoramic-type view showing large, well-defined periapical lesion attached to distal root of tooth #31. The lesion is somewhat ball-shaped and has a radiolucent rim. It has displaced tooth #31. It was diagnosed as a cementoblastoma. There is no suggestion of the expansile nature of this lesion. (B) CBCT axial view revealing expansile nature of lesion *NOT* appreciated on the panoramic image. (C) Thin-slice sagittal CBCT view suggesting expansion. (D) Thin-slice coronal CBCT view confirming the expansion seen in the axial view in (B). The blue arrows show the expansile features of the lesion in (B) and (D).

the cranial vault, the paranasal sinuses, the nasal cavity, the airway, and the cervical spine. Those dentists thinking that a smaller FOV relieves them of all this responsibility are wrong. Moving the area of capture with a small volume sometimes captures pathology in the anatomic areas listed previously. **Figs. 3–5** illustrate this concept.



**Fig. 2.** (A) Axial slice, right condyle with small FOV. The blue arrow in (A) is the internal carotid artery. (B) Axial slice through left condyle with small FOV with anatomy labeled. ([A] From Miles DA. Color atlas of cone beam CT for dental applications. 2nd edition. Hanover Park (IL): Quintessence Publishing; 2013.)



Fig. 3. Illustration of a small FOV volume ( $8 \times 8$  cm) capturing dental bases.

#### ***A Suggested Method for Scan Review***

Even within the medical radiology community there continues debate between the utility of a structured radiology report versus a narrative report.<sup>3</sup> According to Dr Curtis P. Langlotz, Professor and Vice Chair for Informatics in the Department of Radiology at the University of Pennsylvania Health System, approximately 98% of medical radiology residents received no formal training in radiology reporting. Most, apparently (78%), learned the process from a fellow resident. Concerning a structured report, however, he was quoted in the online journal, *Diagnostic Imaging*:

*the purpose of structured reporting is to communicate to colleagues in a clear way and to make that reported information accessible to the software applications that are meant to improve communication.*

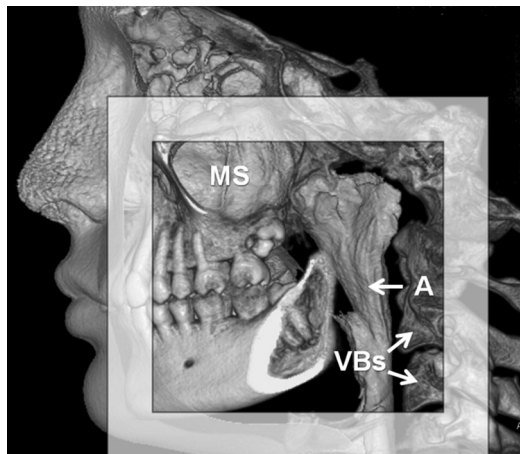


Fig. 4. Even when FOV is moved slightly posteriorly to capture third molar, the airway (A) and vertebral bodies (VBs) are now imaged and must be evaluated. The maxillary sinus (MS) is also in the FOV.



**Fig. 5.** When FOV is moved slightly posterior and superior to capture the condyle, the airway (A), sphenoid sinus (SS), and sella tursica (S) are imaged and must be evaluated.

It seems, then, that the adoption of a formal reporting system in the dental profession that helps dentists and dental specialists review their CBCT volumes competently is desirable. Recently, the authors, in combination with a large cone beam dental software company, released reporting software, called *EasyRiter*, in an attempt to fill this void. The model for the software was developed from their approach to provide structured, interpretive reports for their clinician/clients. So that they themselves ensure that they examine every portion of the volume, the following anatomic regions, when present, are always examined each time in the same fashion to determine abnormal conditions or occult pathology to report to their referring clients:

1. Paranasal sinuses
2. Nasal cavity
3. Airway
4. Cervical structures
5. TMJs
6. Dental findings
7. Other findings

From any abnormal findings discovered, clinical impressions, differential diagnoses, and medical recommendations are provided to a referring dentist supported by the images embedded in the report. In addition, when necessary, citations about the import conditions are included to help assist dentists with their referral to an appropriate medical specialist. A sample report appears in [Appendix 1](#).

According to Wilcox, failure to communicate clearly and effectively to a referring health care provider is 1 of the 3 most common reasons for malpractice suits.<sup>4</sup> The authors agree with this. Wilcox further asserts that the report must be understandable to both the patient and referring clinician. Many of the authors' clients use the reports chairside to present these significant findings to a patient. Unlike medical radiology reports, embedding the pertinent images in the report allows a dentist to visually display to patients a significant finding. The authors think that the use of the formatted report allows clearly communicating the importance of the findings to the clinician, who then subsequently discusses these findings with patients. One example of such a report is in [Appendix 2](#).

## COMMON FINDINGS IN ANATOMIC REGIONS IN CBCT DATA SETS BY ANATOMIC REGION

### *Paranasal Sinuses*

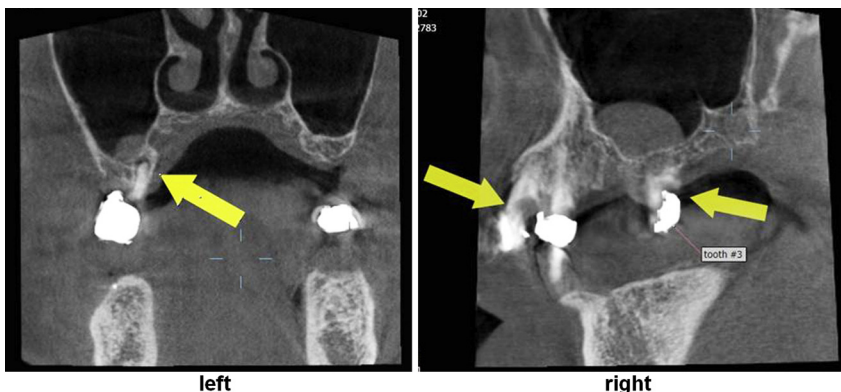
As reported in a previous article by Parks, the paranasal sinuses include the frontal, sphenoid bone, and maxillary sinuses as well as the ethmoid air cell complex. Most dentists are familiar with inflammatory changes that might occur in the maxillary sinuses. Common changes in the maxillary sinuses include mucosal thickening, mucus retention phenomenon (antral pseudocyst), and, although less common, the occasional antrolith. When the inflammatory changes seen in the maxillary sinus are extensive, often the other paranasal sinus spaces are involved. **Figs. 6–9** show examples of common changes.

It is important to consider the possibility of inflammatory change in the other paranasal spaces when significant portions of the maxillary antra are involved. In some cases, this may mean immediate referral to a primary care provider and/or an otolaryngologist for clinical and endoscopic evaluation of all the paranasal sinuses, even if only a portion of the maxillary antra is visualized in the limited FOV scan.

More rarely, sinus mucocoeles (destructive inflammatory lesions, unlike those of the salivary gland type) can also develop in the paranasal sinus spaces; these occur much less frequently than the mucus retention phenomenon (antral pseudocyst) in the maxillary sinuses but when they occur are more commonly located in the frontal and sphenoid sinuses as well as the ethmoid air cell complex. **Fig. 10** shows an example of a mucocoele.

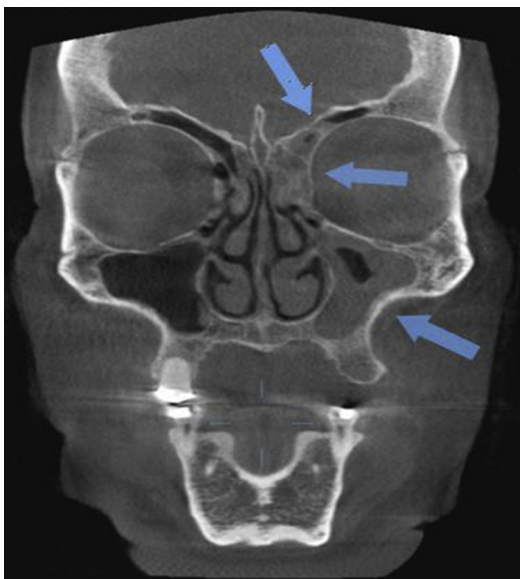
The most common bony radiopacity occurring in any of the antral spaces, especially the frontal sinuses, the ethmoid air cell complex, and sphenoid sinuses, is the osteoma, sometimes called ivory osteoma. Examples are shown in **Fig. 11**.

Many other intrinsic and extrinsic lesions tumors and systemic disorders can affect the maxillary sinus and the other paranasal sinus regions. Complete discussion of these changes is beyond the scope of this article. Most of the radiographic change seen in the paranasal sinus spaces appears as a diffuse, homogeneous radiopacity, less dense than the surrounding bone. The following radiographic changes observed



**Fig. 6.** (*Left*) An example of periapical mucositis—inflammatory change in the right maxillary sinus immediately adjacent to a dental problem, in this case, apical periodontitis. (*Right*) A dome-shaped radiopacity arising from the floor of the right maxillary sinus consistent with a mucus retention phenomenon (antral pseudocyst). Yellow arrows identify gross carious lesions.

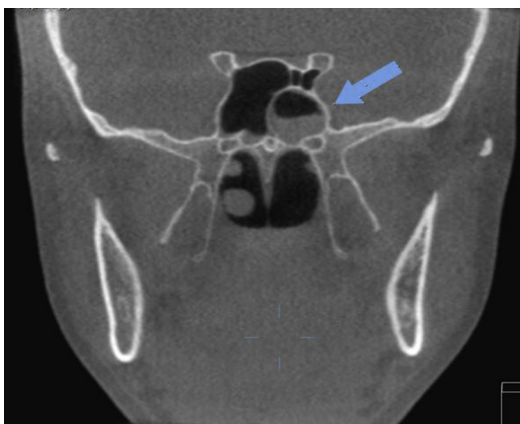




**Fig. 7.** Inflammatory change unilaterally in the left maxillary sinus, left ethmoid air cell complex, and left frontal sinus and ear region, called the *lateral recess*.

within any of the paranasal sinuses should, however, raise a clinician's index of suspicion and should prompt making an appropriate referral:

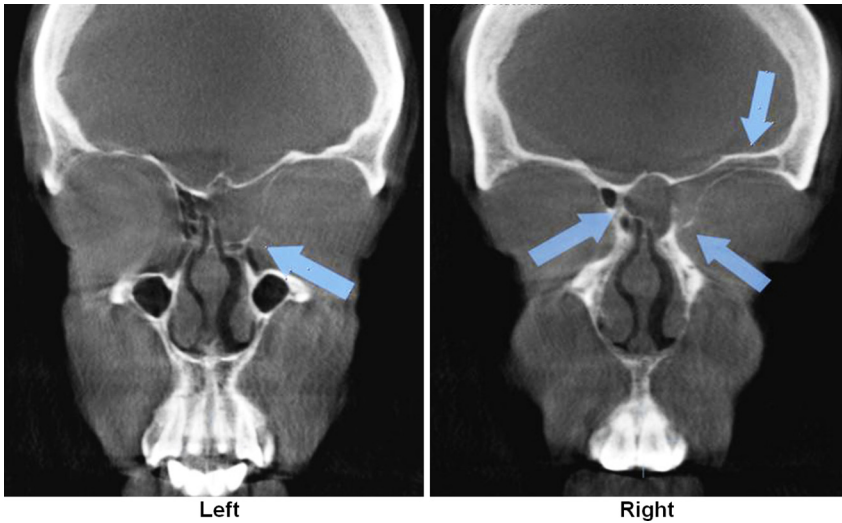
1. Expansion or displacement of the wall of the space (see [Fig. 10](#))
2. Destruction of the bony wall of the space ([Fig. 12](#))
3. Thickening (hyperostosis) of any wall surrounding the space ([Fig. 13](#))
4. A pansinusitis (major portions of multiple spaces opacified) ([Fig. 14](#))



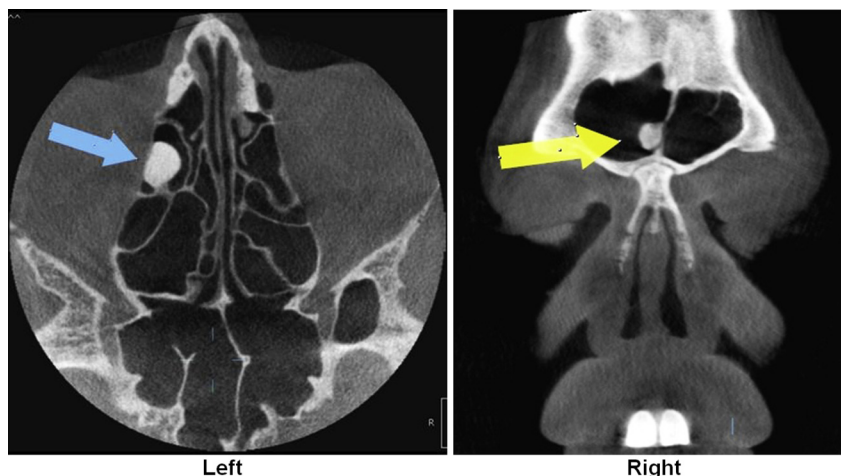
**Fig. 8.** Inflammatory change in the lower half of the left sphenoid sinus.



**Fig. 9.** The upper blue arrow identifies inflammatory change in the right frontal sinus. There is also change in the ethmoid air cell complex and both maxillary antra.

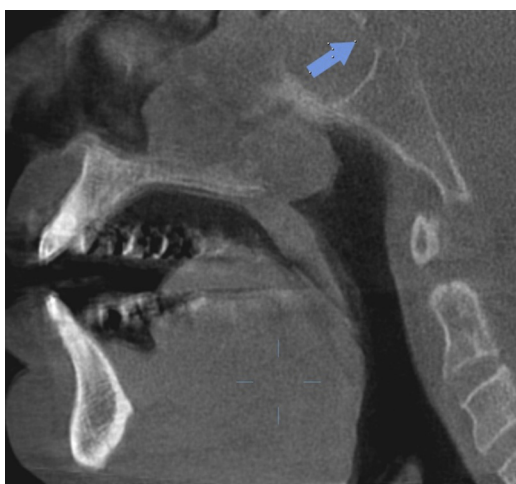


**Fig. 10.** (Left) All the left ethmoid air cell complex appears opacified. There seems to be a displacement of the medial wall of the left orbit by this suspected inflammatory change. Displacement of the orbital wall is not a good sign. (Right) A more anterior slice showing a rounded appearance, obliteration of the ethmoid air cells, and possible extension into the left frontal sinus (upper blue arrow). These changes raise suspicion for a more ominous lesion like a mucocele.



**Fig. 11.** (Left) An osteoma in the right ethmoid air cell complex. (Right) An osteoma in the right frontal sinus.

Patients with the findings seen in the examples of the radiographic changes, listed previously, must all be referred to an otolaryngologist for clinical and endoscopic evaluation. Whether from inflammation or tumor, all these changes result in clinical symptoms for patients of pain; headache; referred pain; and, in many cases, classic signs of a sinus infection, such as rhinorrhea, nasal congestion with or without fever, and, in cases involving a pansinusitis or severe maxillary sinusitis, commonly tooth pain.



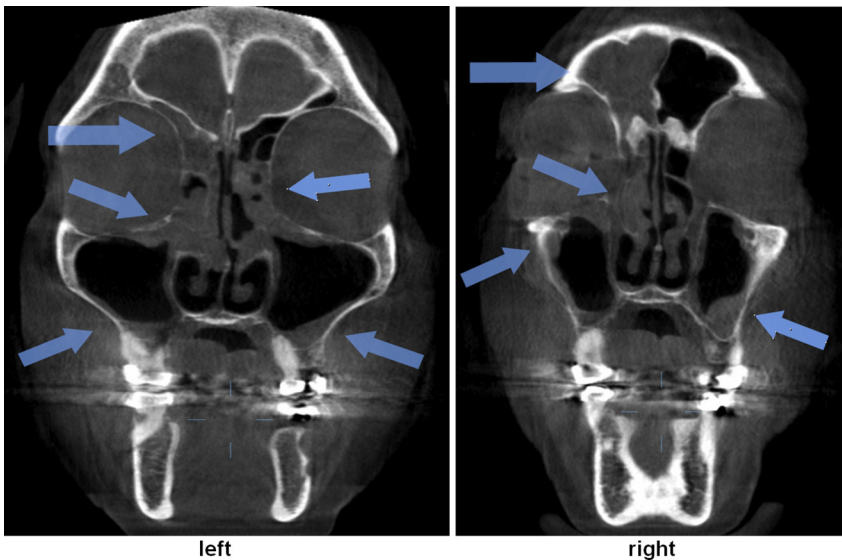
**Fig. 12.** A large lesion occupies the ethmoid air cells and back of the nasopharynx. The lesion also appears to occupy the sphenoid sinus and has caused a loss of bone adjacent to the sella turcica. This dehiscence is an ominous sign.



**Fig. 13.** (Left) There is significant inflammatory change in the sphenoid sinus. All the walls are grossly thickened. This is termed, *hyperostosis*. (Right) The changes seen in the sagittal view on the left are comparable in this coronal section especially along the inferior border of this sinus space.

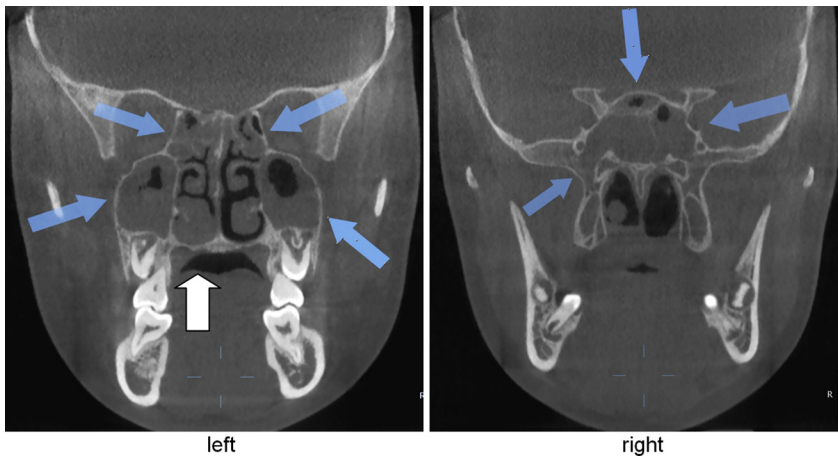
### Nasal Cavity

Common findings that dentists see in the nasal cavity include a deviated septum, enlarged or hypertrophic turbinates and/or the lining mucosa (often narrowing the adjacent meatal spaces), the anomaly called *concha bullosa* (see description elsewhere in this issue), and missing walls usually due to sinus surgery. **Figs. 15 and 16** demonstrate some of these findings and anomalies.



**Fig. 14.** (Left) Mucosal change affecting the inferior portions of both maxillary antra, the ethmoid air cells bilaterally extending into the lateral recess of the left frontal sinus on the right side. The ostiomeatal complex is blocked on both sides (*middle blue arrows*) so that drainage cannot be established and the infection/inflammation persist. (Right) The remainder of this patient's right frontal sinus is totally opacified from extension of the ethmoid air cells and the blocked ostium on that side.

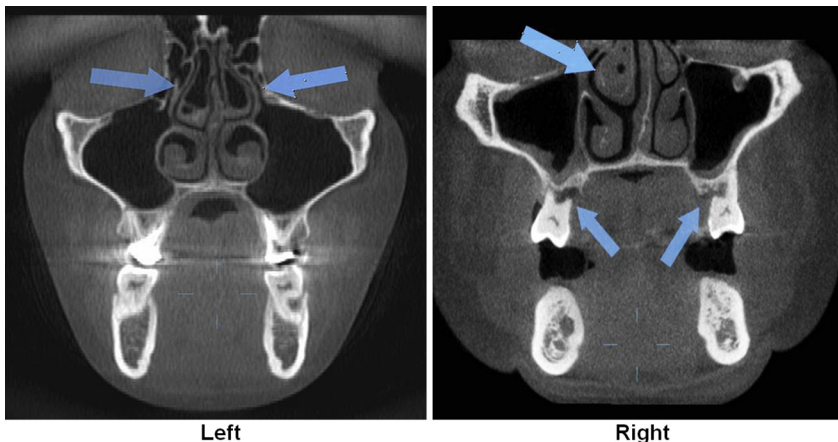




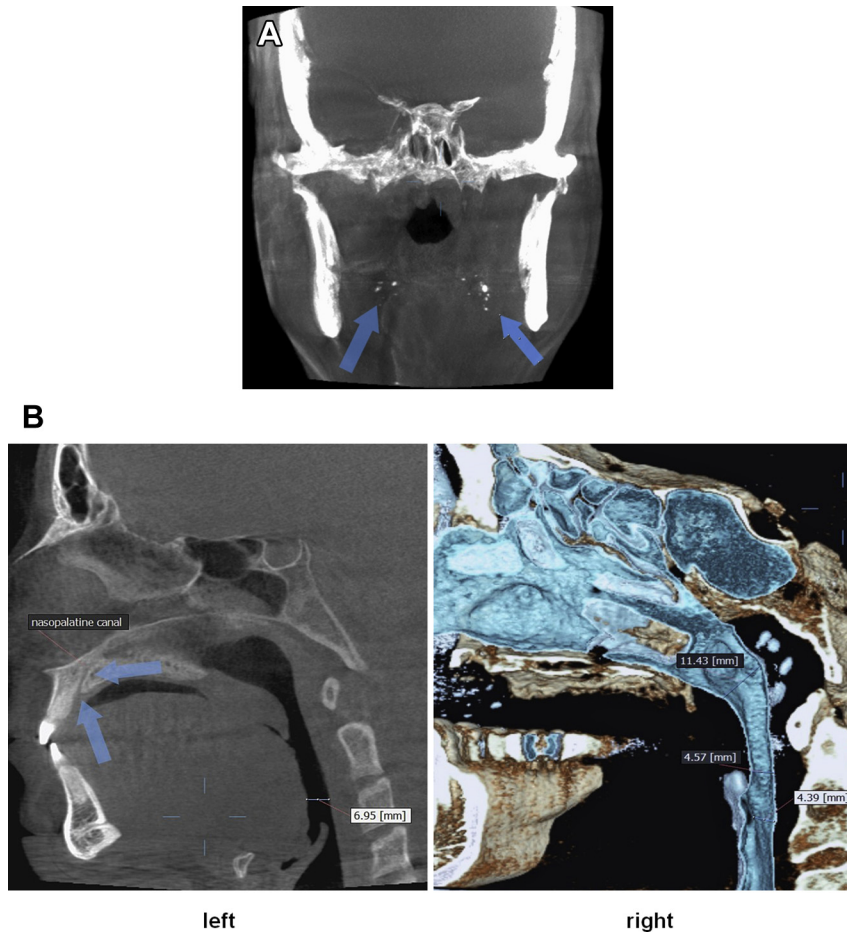
**Fig. 15.** (Left) Blue arrows point to inflammatory changes in both maxillary antra and much of the ethmoid air cell complex. White arrow points to a hypertrophic right inferior turbinate and soft tissue changes that have occluded the inferior meatal space and part of the common meatal space. (Right) Extensive inflammatory change in the same patient in the sphenoid sinuses, both left and right. The right sphenoid sinus even extends into the pterygoid bone (lower left blue arrow), which also shows the inflammatory change. This patient had a severe pan-sinusitis and was referred to an otolaryngologist.

### Airway

Enlarged tonsils and/or adenoid tissues are seen frequently in CBCT volumes. More commonly, there can be calcifications that are single, multiple, unilateral, and/or bilateral, which represent tonsilloliths. Tonsilloliths are concretions of mucus, bacteria, and sometimes fungi that reside in the tonsillar crypts and frequently cause malodor (bad breath).<sup>5</sup> Fig. 17A shows some of these changes.



**Fig. 16.** (Left) Bilateral pneumatization of the middle turbinates, an anomaly called concha bullosa. Both of these spaces are patent. (Right) Inflammatory change within the concha bullosa anomaly (upper blue arrow) with mild septal deviation to the left. Lower blue arrows are simply identifying furcation defects.

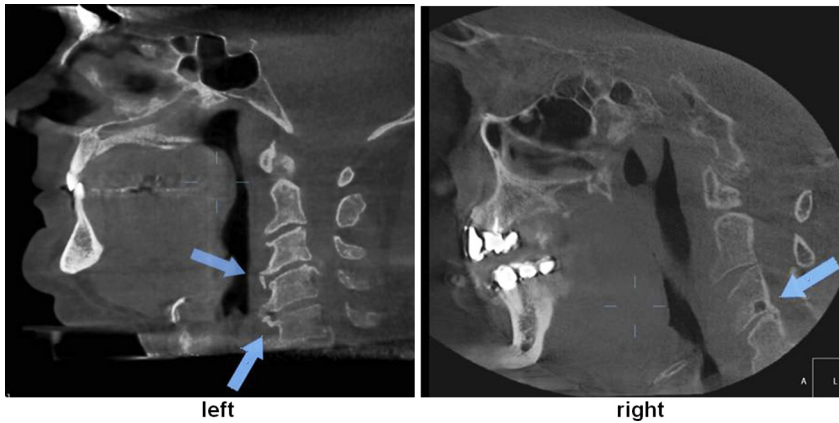


**Fig. 17.** (A) Calcifications in the crypts of the tonsillar tissues in a maximum intensity profile presentation at 10-mm slice thickness. (B) (Left) 2-D gray-scale thin-slice sagittal image, (0.1 mm), showing center region of volume and measurement at narrowest portion of airway. (Right) 3-D color reconstruction at approximately 30-mm slice thickness demonstrating measurements in 3-D with airway opened up.

Dentists and dental specialists who treat patients for sleep-disordered breathing or obstructive sleep apnea (OSA) frequently assess the width, area, and volume of portions of the oral pharynx and pharynx when looking at a patient's airway. A discussion of OSA and the applications/tools of CBCT are beyond the scope of this article. **Fig. 17B** demonstrates the types of images that are useful in OSA.

### ***Cervical Spine***

The changes that are common to osteoarthritis are common in the vertebral bodies and facet joints of the cervical spine. Osteophyte and subchondral cyst formation, loss of joint space, subluxation between 2 joints, and loose bodies are frequently seen in CBCT data sets. These are demonstrated in **Figs. 11–29**. Another change

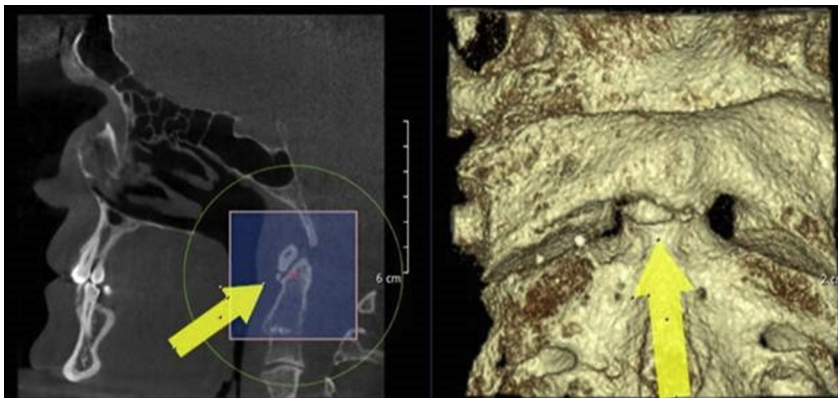


**Fig. 18.** (Left) Osteophyte formation on vertebral bodies C3 and C4. (Right) Subchondral cyst formation on C3. These changes and loss of joint space between the vertebral bodies are common.

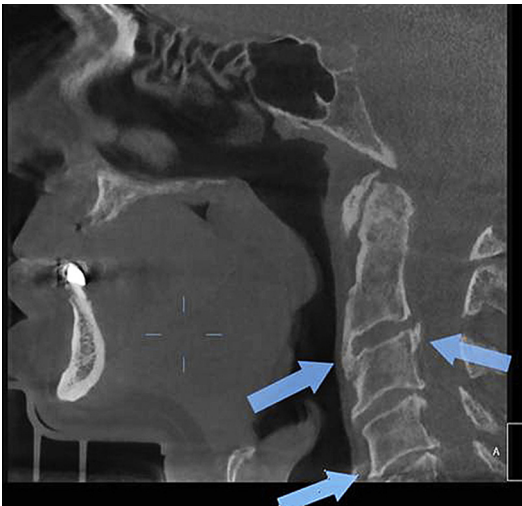
seen in larger FOV volumes associated with the vertebral bodies is calcification of the anterior paraspinal or posterior paraspinal ligaments (see [Figs. 11–20](#)). Radiolucencies that are not consistent with subchondral cyst formation might represent metastases from some of the more common cancers, such as prostate, lung, cervical, and breast cancers. Any change that looks unusual to a clinician is reportable and referral, in most cases back to the primary care provider and/or an orthopedic specialist, internist, or rheumatologist.

### ***Temporomandibular Joints***

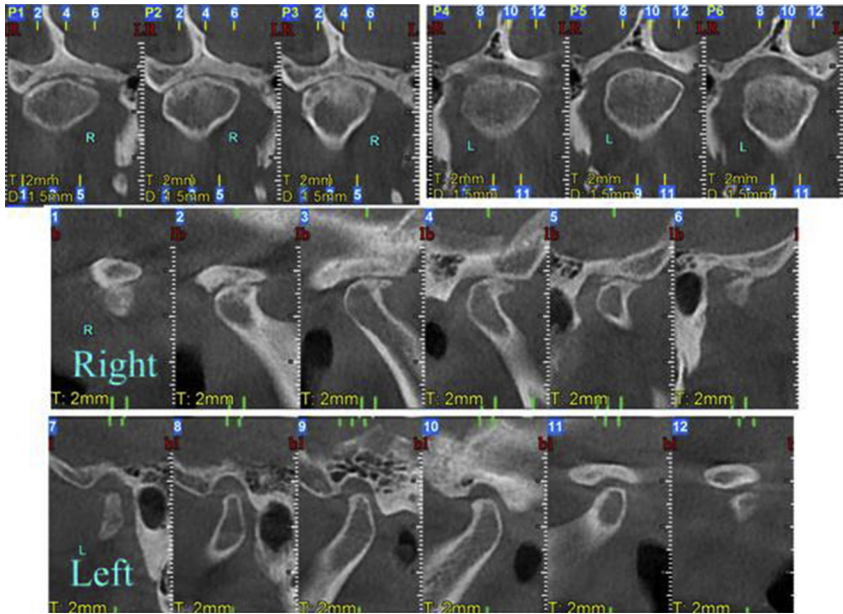
The TMJ complex, at least the condyles and related bony structures, are easily and accurately imaged with CBCT both in 2-D gray-scale imaging and in 3-D color



**Fig. 19.** Loose body (yellow arrows) in atlantoaxial junction in 2-D gray-scale and 3-D color reconstruction. The color reconstruction was performed simply by using a “cube tool” in the *OnDemand3D* software (Cybermed, Irvine, CA).

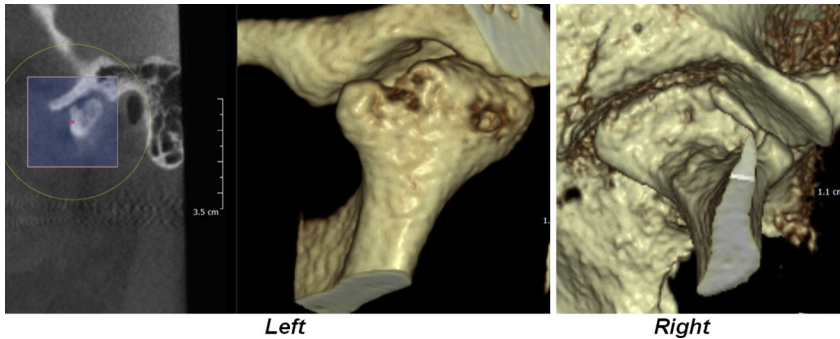


**Fig. 20.** The linear opacities seen between C2 and C3 on both the anterior and posterior surfaces represent calcification of the longitudinal paraspinal ligaments. This finding can be confused with osteophyte formation, which is far more common.



**Fig. 21.** TMJ comparative joint series of serial coronal (top row, right and left joint respectively) and sagittal views (middle row, right joint and bottom row, left joint) showing subchondral sclerosis and subchondral cyst formation of both condylar heads with anterior surface lipping of the left condyle and anterior osteophyte formation of the right. The articular surfaces of the right joint show a shallow fossa configuration and a flattened articular slope of the eminence with loss of the superior joint space. By comparison, the left joint articular surfaces are considered normal. The left condyle appears somewhat inferiorly positioned in the fossa.





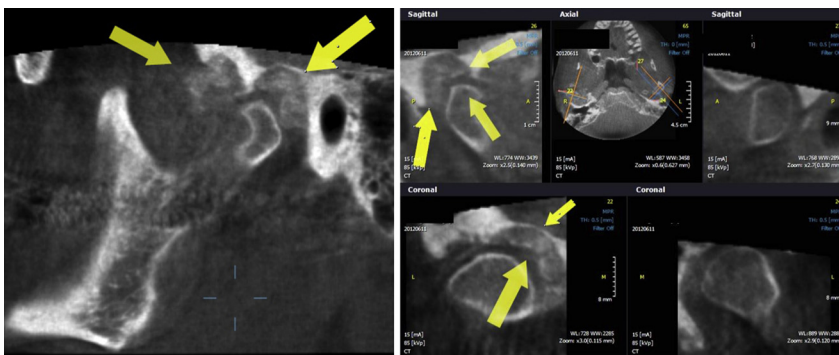
**Fig. 22.** Osteoarthritic changes on TMJ condyles. (Left) Surface erosions. (Right) Lipping of the anterior surface and comparable change on the articular eminence latterly.

reconstruction. Similar to the changes seen in the vertebral bodies, subchondral sclerosis, subchondral cyst formation, loose bodies, and alterations of joint space are optimally visualized. Unlike the cervical spine, synovial chondromatosis is seen with some frequency in the TMJ complex. **Figs. 22–24** show examples of all these changes.

### Dental Findings

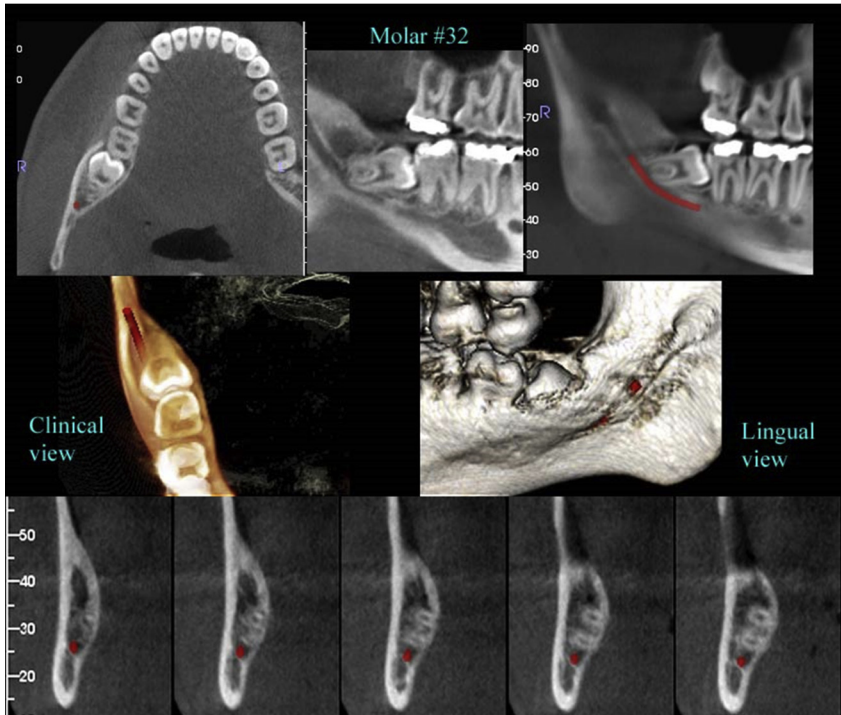
Because a dentist or dental specialist has examined and charted a patient as well as taken a complete dental and medical history, most oral maxillofacial radiologists confine their description of the changes in the section bone levels, missing teeth, lesions of endodontic origin (new or residual), impactions, and malocclusion in this dental findings section of the report. If there is an odontogenic cyst or tumor; suspected systemic condition, such as osteomyelitis or systemic disease; fracture; or symmetry, these are also reported by most radiologists in this section.

More often an oral maxillofacial radiologist is looking to uncover occult pathology that the referring dentist is not looking for because it is not the primary reason for the cone beam examination. If dentists or nonradiologist dental specialists decide to examine their own volumes, however, then they are held to the same standard of



**Fig. 23.** Multiple, diffuse radiopacities in the right TMJ space apparently displacing the condyle inferiorly. This is a case of synovial chondromatosis.

**A**

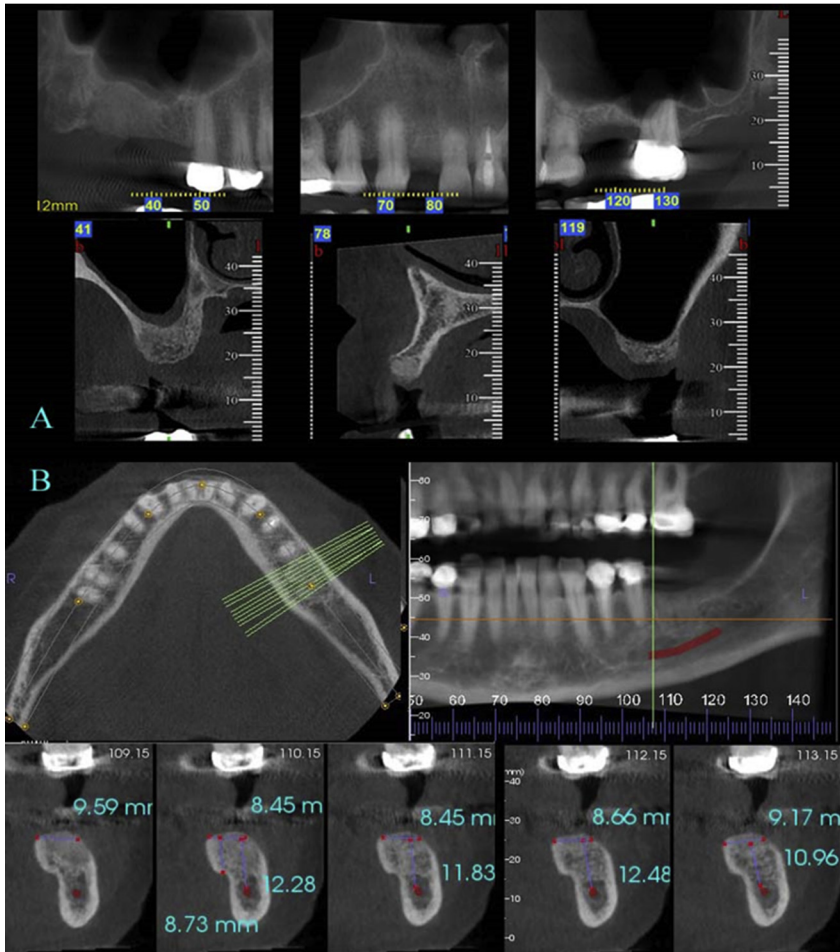


**Fig. 24.** (A) A mandibular impact third molar image series: these images show the anatomic relationship of the impacted molar to the adjacent second molar, if root resorption is occurring, the perifollicular space for abnormalities, the clinical/surgical access and lingual mandibular views, and the position of the inferior alveolar canal to the impact root apices. Such images allow for a presurgical treatment plan that can help reduce the possibilities of undesirable treatment outcomes. (B) Various maxillary and mandibular edentulous cross-sectional views showing the ridge crestal configurations, arch widths, vertical bone heights to the sinus/nasal cavity floors, sinus inflammation, bone grafting ridge preservation, the presence of a mandibular lingual surface concavity, and crestal distance to the colorized inferior alveolar canal. The associated guideline measurements can further assist dental implant treatment planning.

care as an oral maxillofacial radiologist and required to find and report any unusual conditions that may reside in that volume. This is a significant responsibility, one that might require additional training for some dentists. **Figs. 25** and **26** show some of the dental changes for which clinicians frequently request help. Such requests may include concerns for the relationship of impacted teeth to adjacent structures, such as the inferior alveolar nerve canal and sinus floors, the unerupted maxillary canines to the root apices of the maxillary incisors, and, for dental implants, the location of the inferior alveolar nerve canal and bone configurations of the ridge.

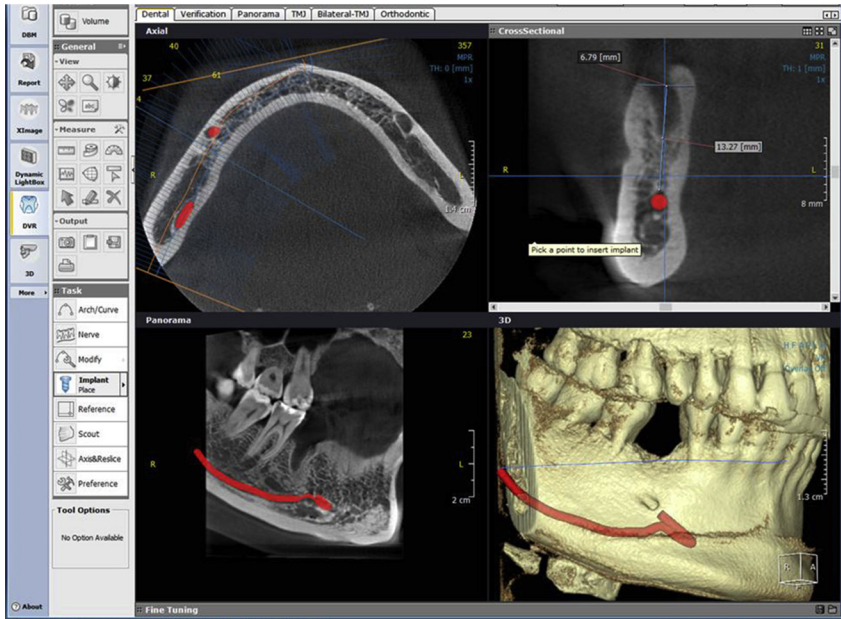
### Other

The “Other” section of the authors’ structured report allows identifying for a clinician many conditions or findings that need referral of a patient back to the primary care

**B****Fig. 24.** (continued)

provider or to a medical care provider/specialist. In this section, the authors report cranial calcifications; calcifications in the cervical and/or parasellar segments of the internal carotid arteries; calcifications of other arteries, such as vertebral; calcifications in the facial or other soft tissues, such as sialoliths, miliary osteoma, and calcified lymph nodes; and calcifications of the cartilaginous horns of the thyroid gland. Many of these calcifications, such as those of the pineal gland, choroid plexuses, and superior horns of the thyroid cartilage, are physiologic and occur with aging. All arterial calcifications must be referred, however, because they are always related to hypertension and stroke risk as well as dysglycemia and/or renal problems. As common as type 2 diabetes mellitus is in North America, dentists who examined CBCT volumes encounter these calcifications frequently. In long-standing type 2 diabetes mellitus, patients who are uncontrolled or undiagnosed may also have significant renal problems often resulting in end-stage renal disease (ESRD). The arterial changes as the kidney shuts down

**A**



**Fig. 25.** (A) Implant site measurement for placement of a single endosseous implant fixture using a simple, intuitive implant planning software (Cybermed, Irvine, CA). (B) Final try-in of the implant icon from the case, showing its relationships within the alveolar bone, the cortical bone, and the inferior alveolar nerve. The measurements and data from the CBCT scan will then be sent to a laboratory for surgical guide construction. (C) After construction of a surgical guide seen in the top right image, various implant fixtures are visualized in their locations relative to the anatomic structures including the inferior alveolar nerve. ([C] Courtesy of Cybermed, Irvine, CA.)

are striking, widespread, and easily recognizable because they usually are seen in several carotid arterial segments, most frequently bilaterally.<sup>6,7</sup>

Examples of most of these findings are shown in [Figs. 26–31](#).

## REPORTABLE FINDINGS

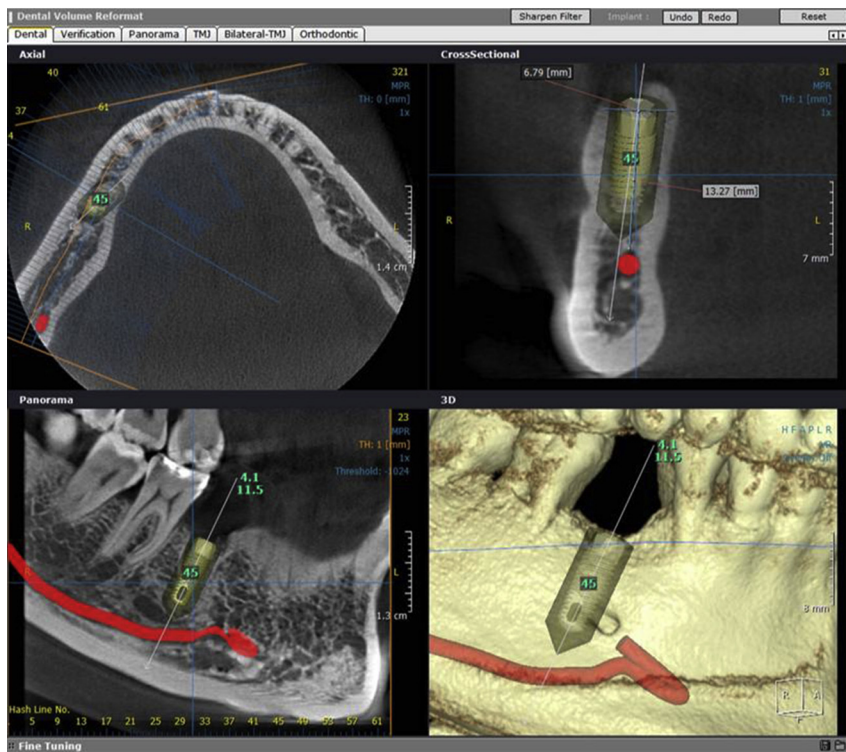
**Table 1** is an attempt to list frequently encountered reportable findings that the authors have seen in the thousands of volumes examined, all of which involved referral to the medical community for follow-up evaluation and management.

## SUMMARY—WHY DO REPORTS?

It is the responsibility of health care providers to acquire information data from patients to best determine the health status of patients, if treatment is indicated, and to provide a basis for informed patient consent. Although such information is usually directed toward a primary condition, there is also the possibility that secondary information is obtained that also could have an influence on a patient's health. The use of CBCT for dental treatment planning poses such a situation in which the additional data in



B



C

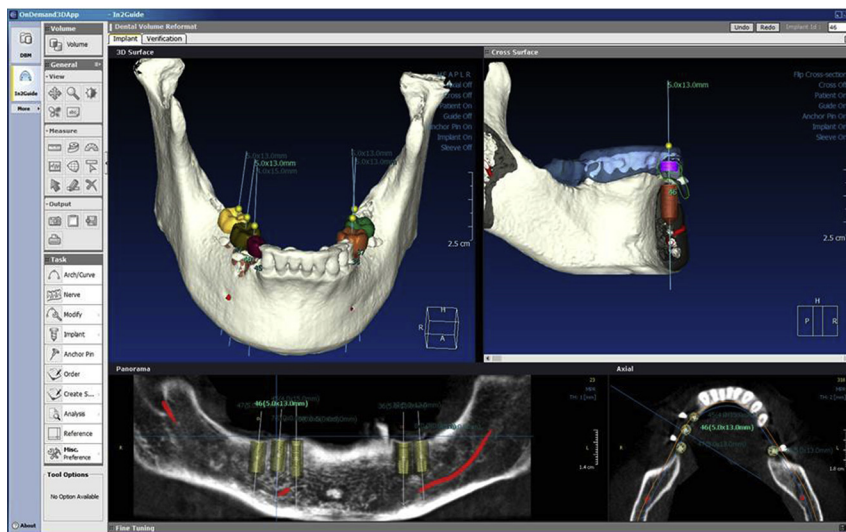
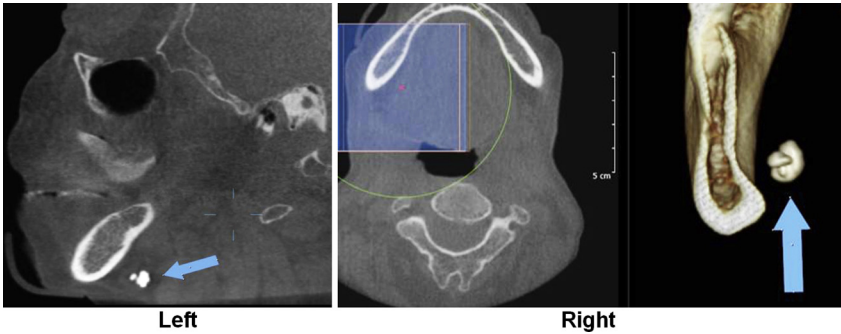
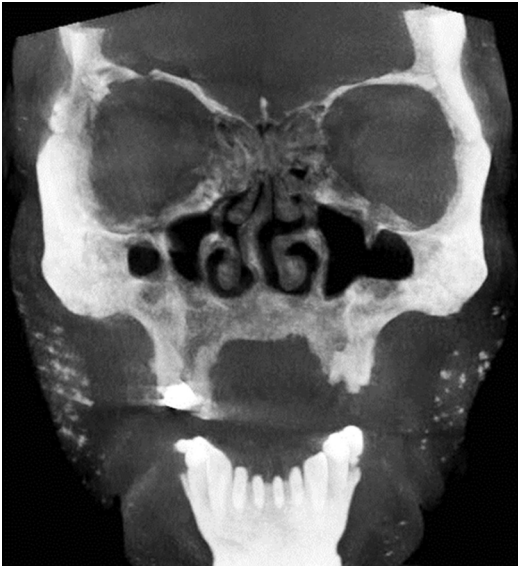


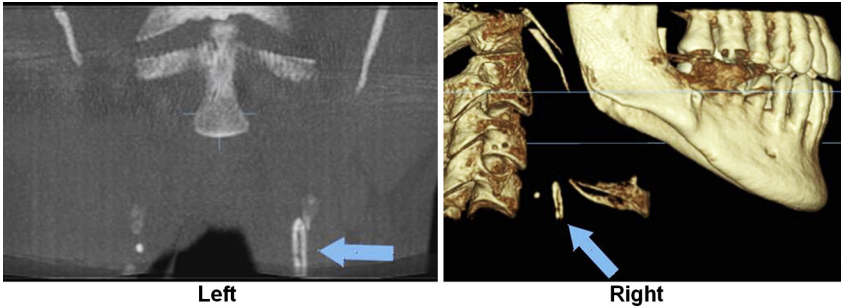
Fig. 25. (continued)



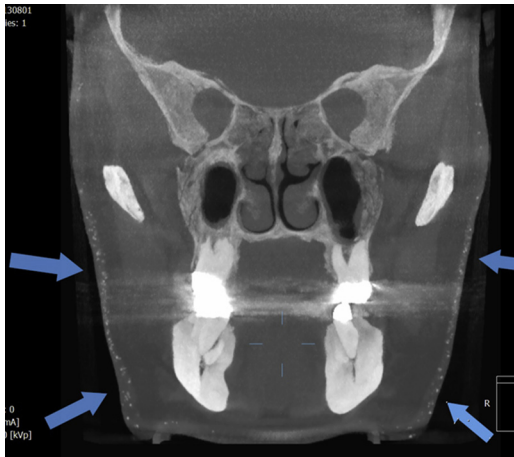
**Fig. 26.** An example of a sialolith in the right submandibular salivary gland in both 2-D sagittal gray-scale image (*left*) and 3-D color reconstruction (*right*). This stone is probably at the hilum of the gland.



**Fig. 27.** A coronal section, at 10.0-mm thickness, using a maximum intensity profile tool to demonstrate bilateral parotid sialoliths seen in some autoimmune diseases like Sjögren.



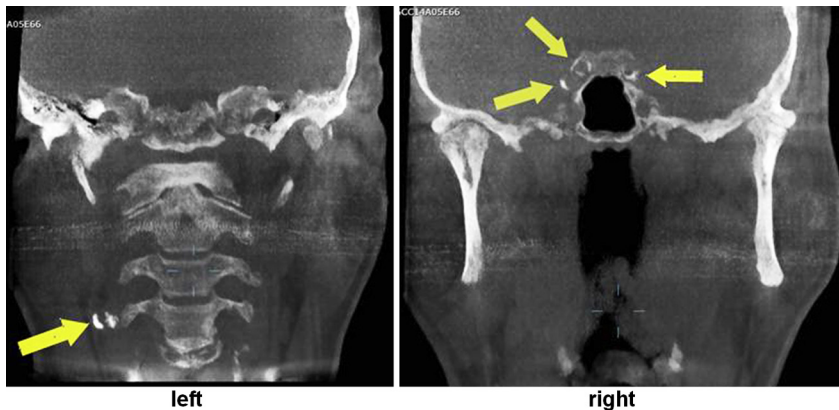
**Fig. 28.** There is unilateral calcification of the superior horns of the thyroid cartilage. The blue arrow shows the most superior portion of this ligament on the left side as it approaches its insertion into the posterior segment of the left hyoid. The right is a 3-D color image. These physiologic changes in the thyroid cartilage can be mistaken for carotid calcifications.



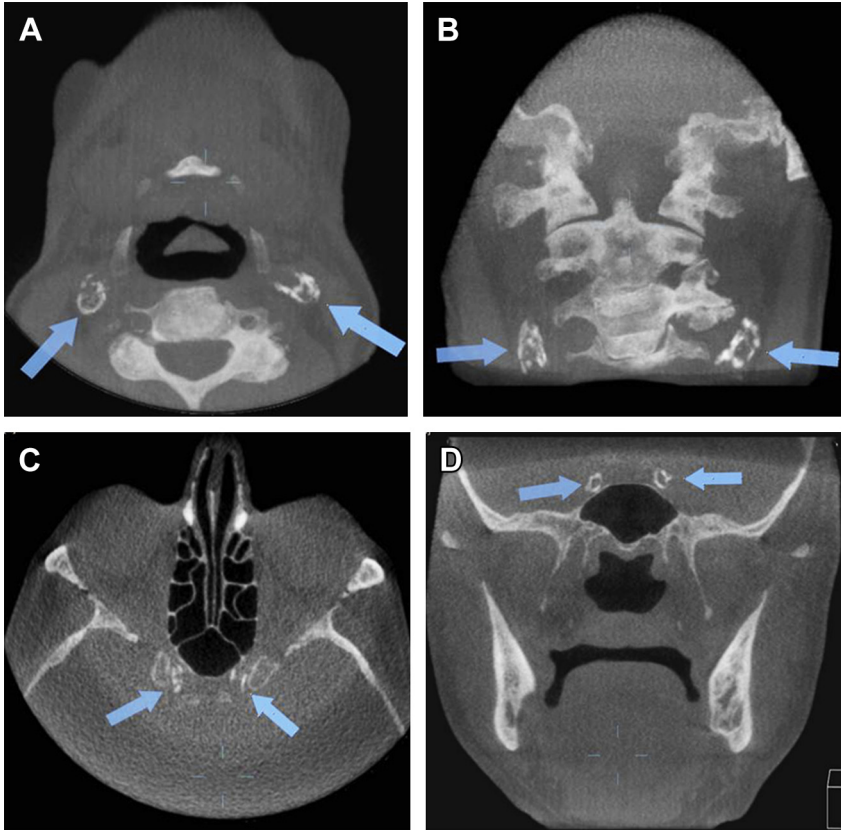
**Fig. 29.** Multiple, bilateral calcifications in the facial soft tissues consistent with miliary osteoma. Also termed, *osteoma cutis*, these calcifications are a metaplastic reaction to 2 things, such as inflammation, trauma, and even neoplasia.

the acquired image volume that are outside of the scope of the primary dental concern could detect systemic conditions that possibly directly influence the overall health and longevity of a patient. Thus, data collection and reporting the findings from the entire CBCT image data volume are a professional responsibility mandate (see the article elsewhere in this issue by Friedland and Miles).

As such, from knowledge of possible health related findings detected in the CBCT image data which are not directly associated with the primary dental concern, patients can make informed decisions. The CBCT report becomes a component of the informed consent standard of care. Who provides the report may not be as important



**Fig. 30.** (Left) A diffuse, sclerotic plaque at the level of C3/C4 (the bifurcation of the internal and external carotid artery region) representative of a carotid plaque. (Right) Carotid plaques in both the left and right internal carotid arteries in the parasellar region, also known as the carotid cistern. In this case, the patient should be referred back to the primary care provider for evaluation of hypertension and stroke risk.



**Fig. 31.** (A–D) Bilateral circumferential carotid plaques in both the cervical and parasellar segments of the internal carotid arteries. These plaques are more indicative of medial arterial calcification, often seen in undiagnosed or uncontrolled type 2 diabetes mellitus and sometimes in ESRD. Patients with this type of appearance and widespread distribution of calcifications are candidates for below-the-knee amputations if not aggressively treated.

| Table 1<br>Reasons and referrals from findings in CBCT scans                           |                                                       |
|----------------------------------------------------------------------------------------|-------------------------------------------------------|
| Finding/Clinical Impression                                                            | Possible Referral                                     |
| Pansinusitis                                                                           | Primary care provider and/or otolaryngologist         |
| Mucocele                                                                               | Primary care provider and/or otolaryngologist         |
| Antro-oral defect                                                                      | Oral maxillofacial surgeon                            |
| Deviated septum and/or hypertrophic turbinate                                          | Otolaryngologist                                      |
| Mastoiditis/cloudy mastoid air cells                                                   | Otolaryngologist                                      |
| Enlarged tonsils and adenoids                                                          | Primary care provider and/or otolaryngologist         |
| Narrowed airway                                                                        | OSA specialist                                        |
| Cervical spine changes                                                                 | Primary care provider and/or an orthopedic specialist |
| Loose bodies, TMJ                                                                      | TMJ specialist or oral and maxillofacial surgeon      |
| Tonsilloliths                                                                          | Otolaryngologist                                      |
| Carotid plaques (cervical)                                                             | Primary care provider                                 |
| Medial arterial calcification (bilateral, circumferential cervical, and/or parasellar) | Primary care provider                                 |
| Pineal gland calcification (greater than 1 cm)                                         | Primary care provider                                 |



as whether or not a report is actually performed. The quality, accuracy, and use of the report are subject to medicolegal scrutiny, and knowledge of such issues determines whether or not a primary provider or a secondary radiology reader evaluates the image data and issues the final report.

## SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.cden.2014.04.006>.

## REFERENCES

1. Miles DA, Danforth RA. A clinician's guide to understanding cone beam volumetric imaging. Special Issue. Academy of Dental Therapeutics and Stomatology, PennWell Publications; 2007. p. 1–13. Available at: [www.ineedce.com](http://www.ineedce.com).
2. Miles DA. Interpreting the cone beam data volume for occult pathology. *Semin Orthod* 2009;15:70–6.
3. Howl-Whitney LJ. Radiology reports: are structured systems the answer?, RSNA 2013. Diagnostic Imaging, Practice Management; 2013. Available at: <http://www.diagnosticimaging.com/rsna-2013/radiology-reports-are-structured-systems-answer?>.
4. Wilcox JR. The written radiology report. *Appl Radiol* 2006;33–7.
5. Shetty D, Lakhkar B, Shetty CM. Images: Tonsillolith. *Indian J Radiol Imaging* 2001;11:31–2.
6. Lehto S, Niskanen L, Suhonen M, et al. Medial arterial calcification a neglected harbinger of cardiovascular complications in non-insulin-dependent diabetes mellitus. *Arterioscler Thromb Vasc Biol* 1996;16:978.
7. Miles DA. Atlas of cone beam imaging for dental applications. 2nd edition. Quintessence Publishing; 2013. p. 283–298, 349–59.





## **Temporomandibular Joint Imaging Using CBCT: Technology Now Captures Reality!**

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Diplomate, American Board of Oral Medicine

### **Introduction**

Over many years dentists and dental specialists have moved from transcranial plain film images through tomography and conventional CT as well as specialized panoramic imaging of the temporomandibular joint complex to arrive at Cone Beam CT (CBCT). This latest imaging modality is making life easy for those clinicians who must evaluate the hard tissues of the temporomandibular joint complex in patients with orofacial pain. Now, for the first time, we can actually visualize both pathology and anatomy in high resolution thin slice grayscale views, 3-D color reconstructed views and even more detailed views using virtual endoscopy and robust third-party software. No longer are we confined to "scout" film panoramics, linear or complex tomography or even high dose, less resolute conventional CT for visualizing the condylar head. Radiographic interpretation of the temporomandibular joint complex including the condyle using CBCT imaging allows clinicians to find more subtle osteoarthritic changes such as subchondral cysts, subchondral sclerosis, osteophyte formation, surface erosion and bony remodeling consistently and with more certainty to make their clinical decision-making simpler. Let's now examine some of these osteoarthritic changes for which CBCT imaging makes their characterization easy.

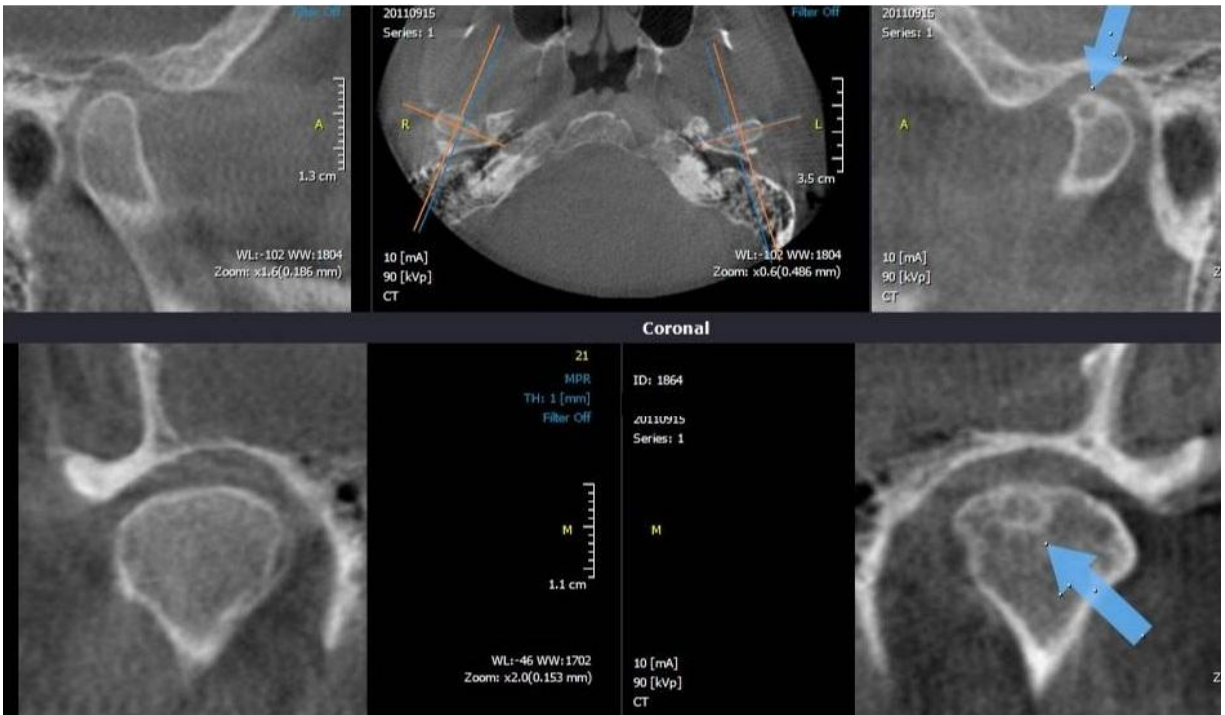
## Subchondral Cyst Formation

Subchondral cyst formation is an early indicator of osteoarthritic changes in the joint surface. I cannot honestly say that I have a good example, even after 35 years of looking at panoramic and other TMJ images using tomography or other plain film techniques, of a subchondral cyst. However, having looked at over 12,000 CBCT scans, I can easily identify such cysts and embed images of them into reports that I produce for my clients. Figure 1 demonstrates examples of subchondral cyst formation.



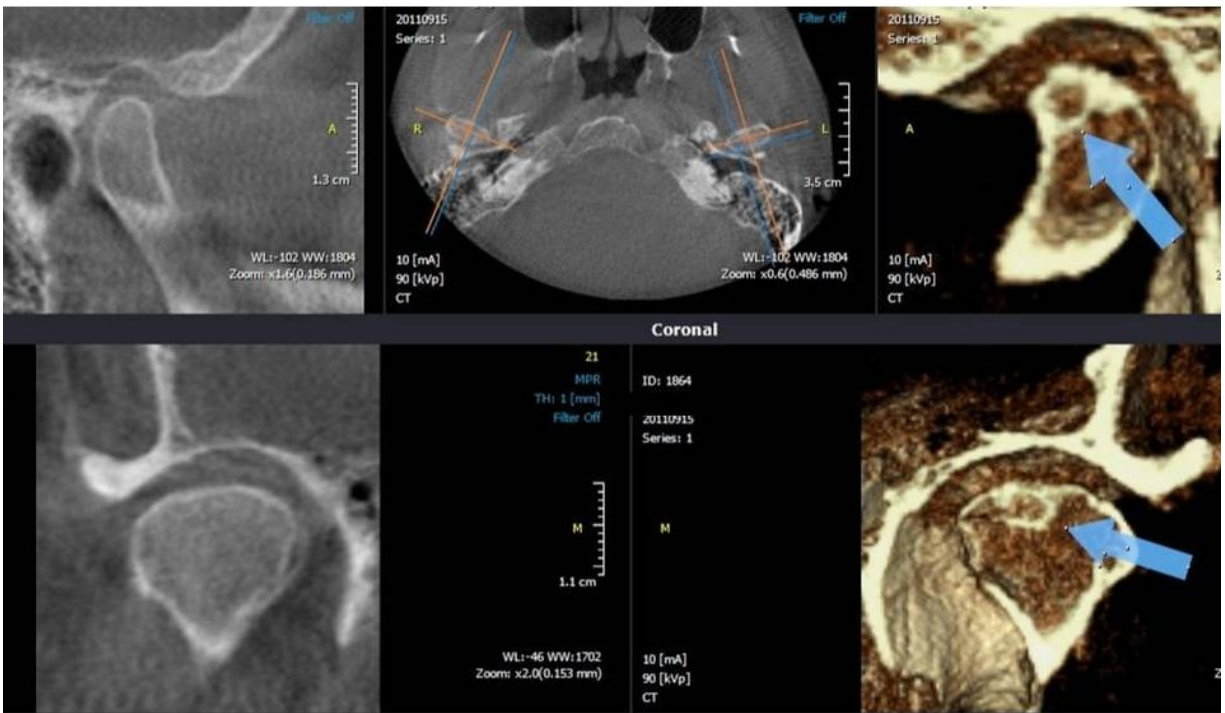
**Figure 1a.** Small circular radiolucency seen on the left condyle in the sagittal plane just inferior to the cortical margin. **Figure 1b.** The same lesion seen in the coronal plane of section. In this view it is more ovoid and appears to have a septation.





C

**Figure 1c.** the same lesion seen reformatted in the OnDemand3D software for a bilateral TMJ comparison. The right condylar head appears normal, the left reveals the same lesion seen in figures 1a and 1b above.

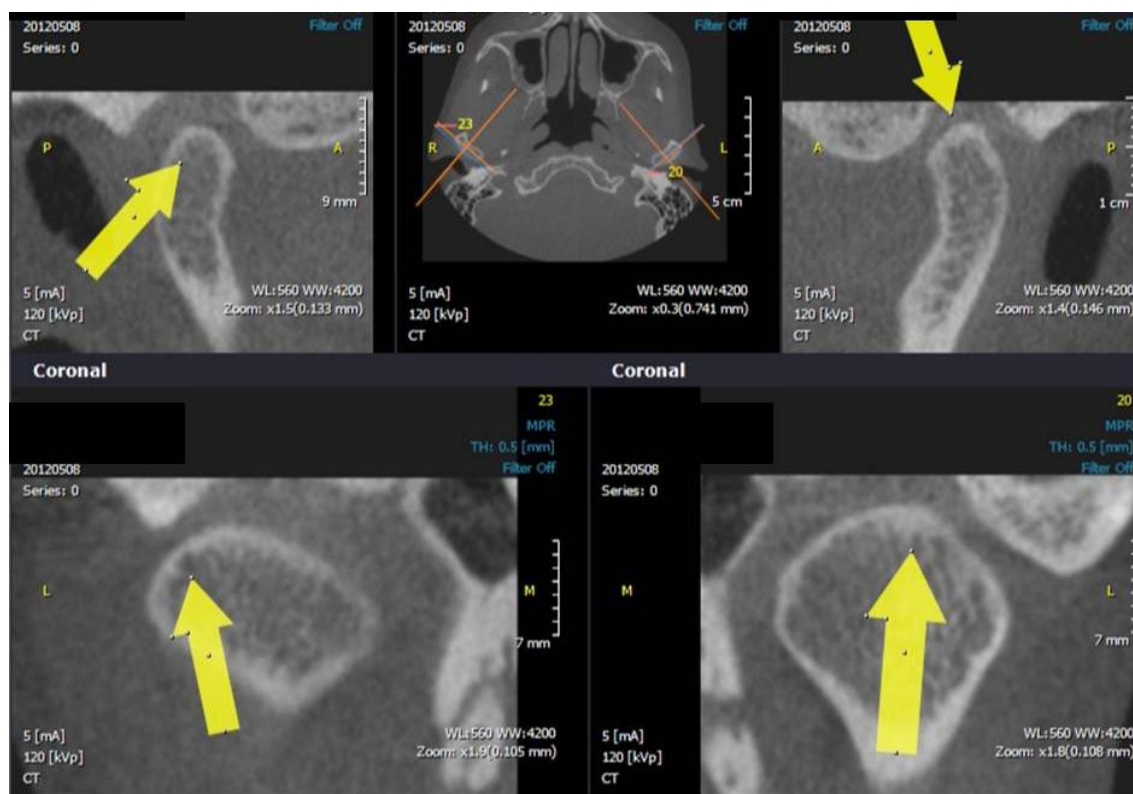


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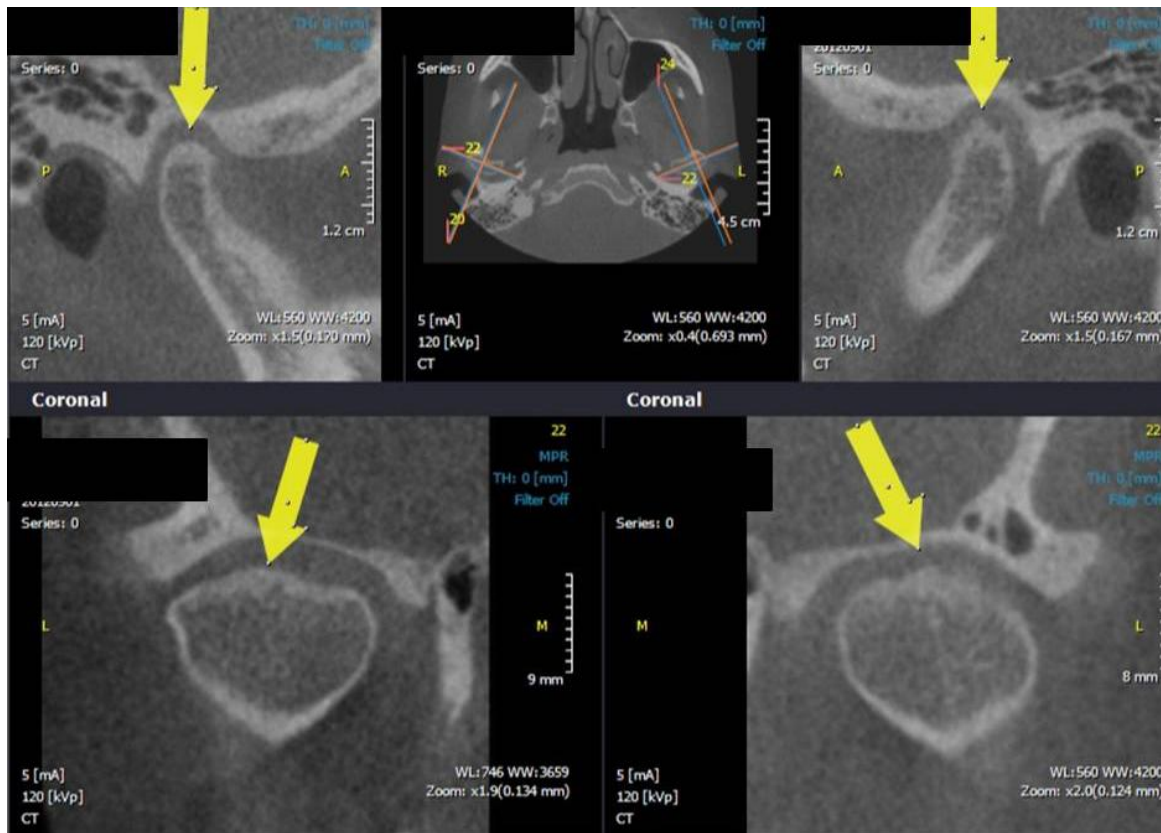
**Figure 1d.** Subchondral cyst formation visualization in thin slice (10mm) 3-D reconstructed view.

## Subchondral Sclerosis

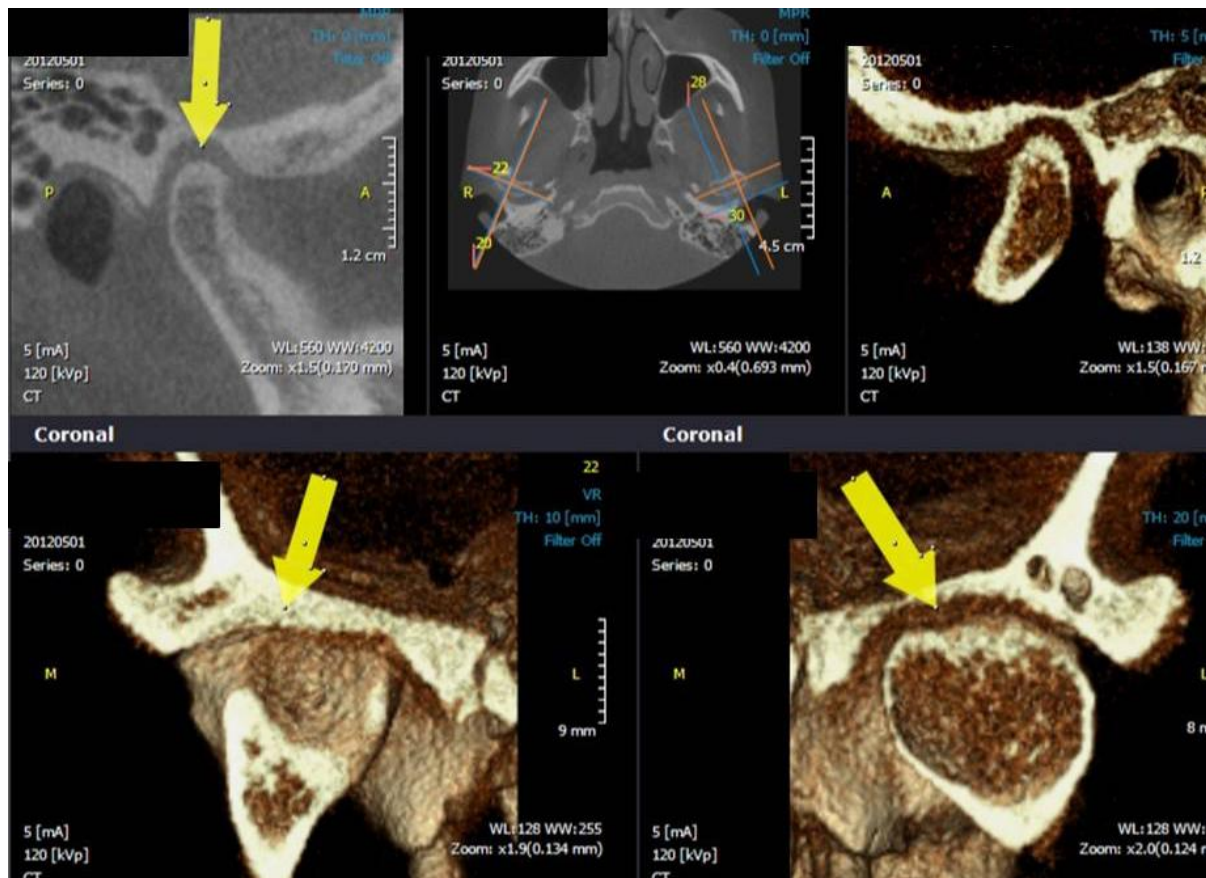
Subchondral sclerosis is an increased intensity or thickening of the cortex below a cartilaginous surface. It can occur on the condylar head or on the opposing surface of the glenoid fossa. It is often seen in conjunction with subchondral cyst formation. Loss of joint space, subchondral sclerosis and subchondral cyst formation are considered the radiographic hallmarks of osteoarthritis. In long-standing rheumatoid arthritis there is also a tendency for the joint surface, especially in the TMJ complex, to exhibit sclerotic change. This cortical alteration has been identified in the past even on conventional panoramic images, either on film-based images or with newer digital, solid-state detectors.



**Figure 2a.** Thin slice sagittal and coronal reconstructed views showing subchondral sclerosis on the left condylar head and subchondral cyst formation on the right.



**Figure 2b.** Subchondral sclerosis is seen on both condylar heads in these thin slice sagittal and coronal reconstructions.



**Figure 2c.** 3-D color reconstructions in 10 mm sections reveal the subchondral sclerosis on these condylar heads. In addition on the right condyle there is some mild lipping towards the lateral pole. Lipping is also a sign of osteoarthritic change.

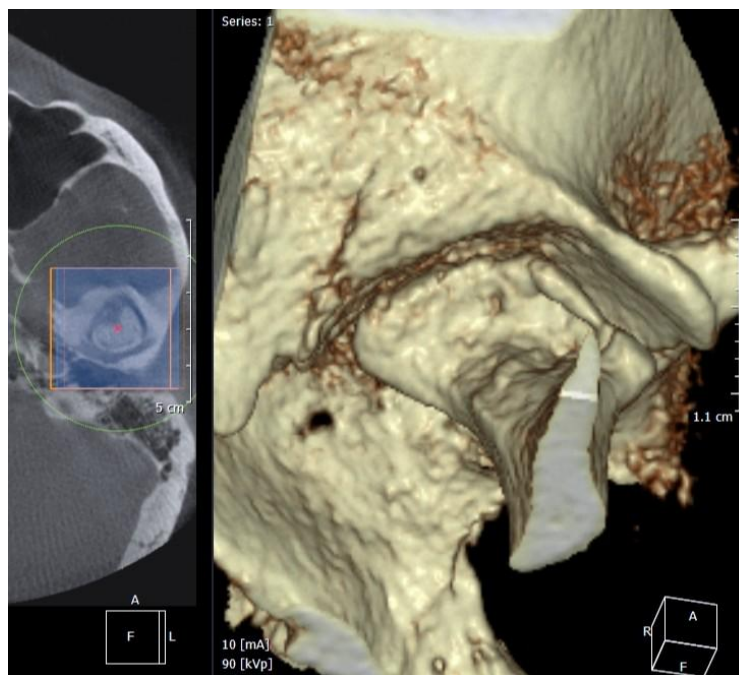
## Lipping

The formation of a liplike structure, as at the articular end of a bone in osteoarthritis (Source: <http://www.biology-online.org/dictionary/Lipping>). With older imaging modalities we often spoke of a "bird beak" appearance which was indicative of an osteophyte and/or osteoarthritic change. With 3-D color CBCT imaging we now see that there are very few "bird beaks". Tomography, transcranial and panoramic views used in the past underestimated of the changes and gave a false appearance depending on the slice thickness or from not viewing the condyle from a truly lateral perspective. Figures 3a to figure 3c demonstrate the past problem in the future solution.

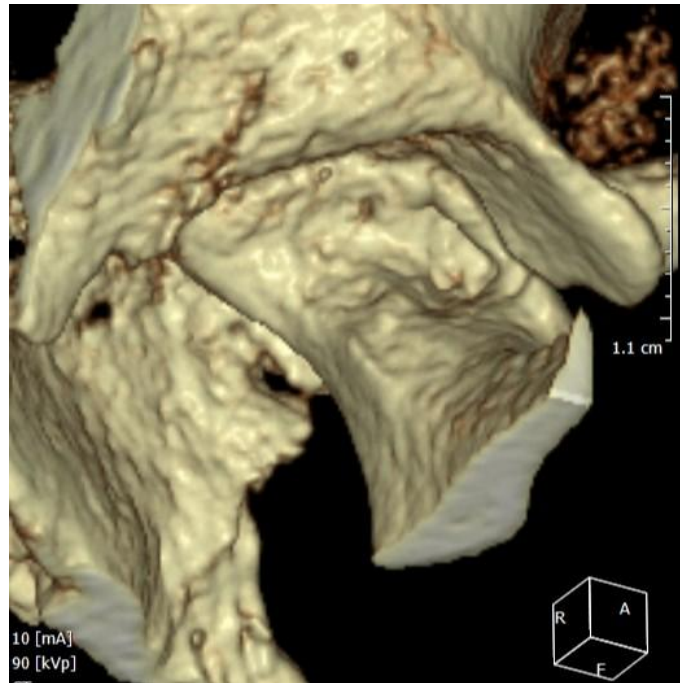




**Figure 3a.** A thin slice (0.1mm) sagittal view through the patient's left condyle showing a projection on the anterior surface of the condylar head. In the past this would've been called a "bird beak". This appearance along with the loss of joint space would seduce the clinician into calling this osteoarthritis.



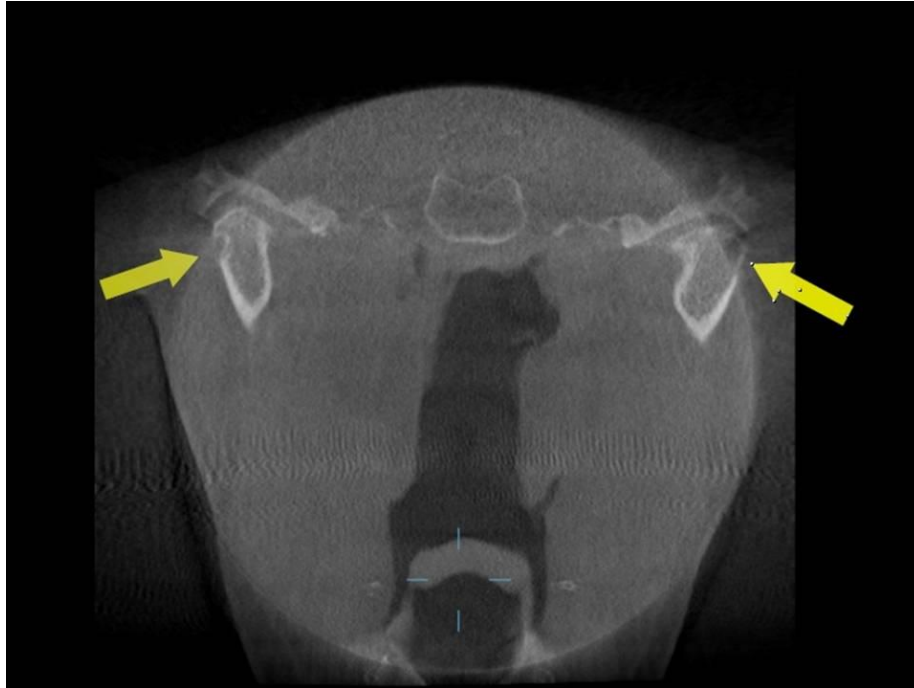
**Figure 3b.** Using a "cube tool" in a third-party software called OnDemand3D (CyberMed, Irvine, CA), a 3-D color reconstruction confirms that there is a deep pterygoid fovea and significant "lipping" on the anterior aspect of the condyle. There is no bird beak.



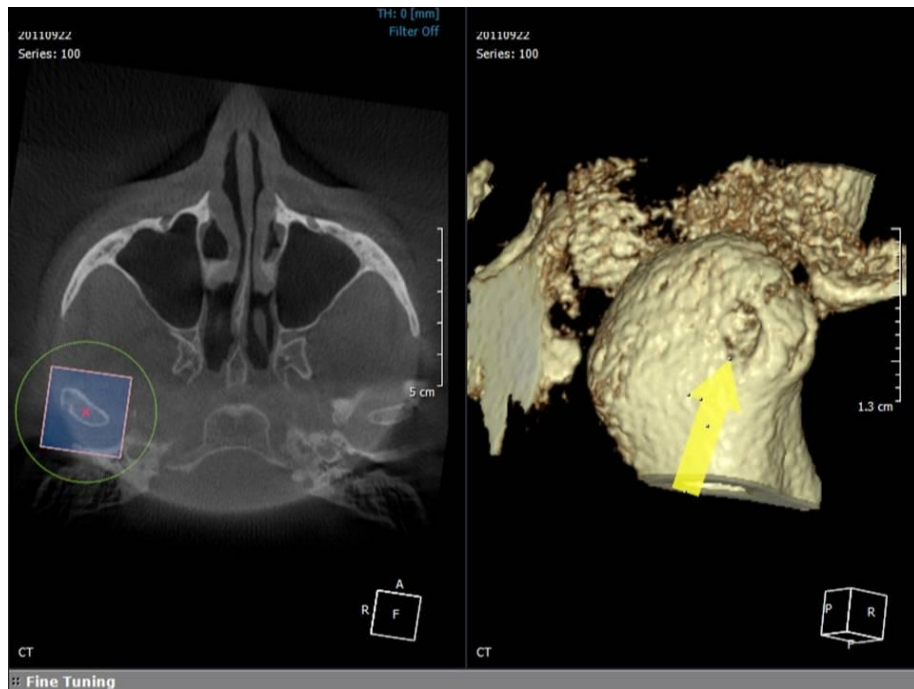
**Figure 3c.** a close-up of the 3-D color reconstruction, slightly rotated, to help the clinician visualize the true morphology of the condylar head.

### Surface Erosions

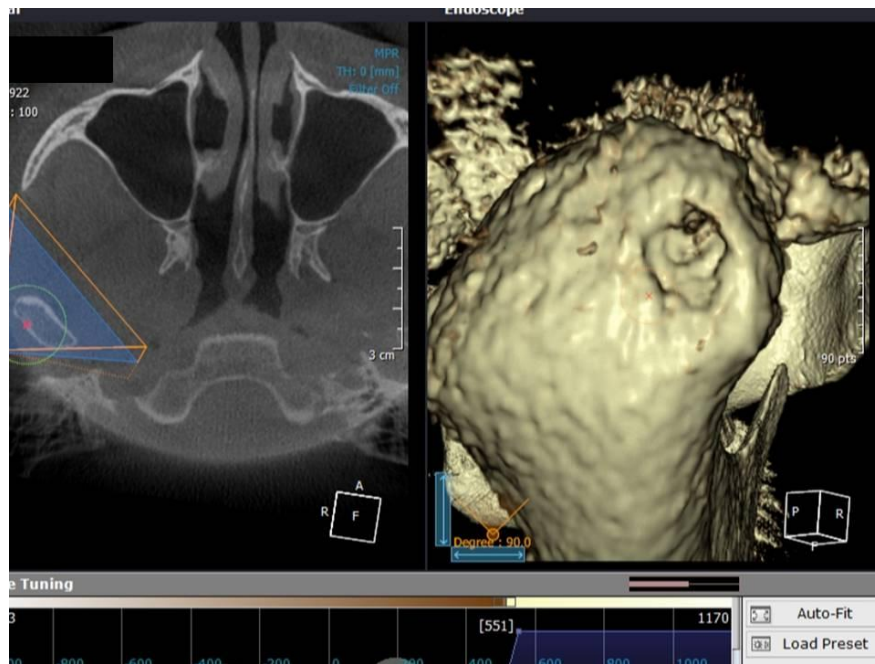
Surface erosions are also common features in osteoarthritis. Until now these changes have been more difficult to demonstrate on the TMJ condyles. However CBCT imaging, especially 3-D color reconstructions, allows the clinician to visualize these smaller surface changes like never before.



**Figure 4a.** Radiolucencies on each condyle near the lateral pole suggestive of erosions.



**Figure 4b.** 3-D color reconstruction using the "cube tool" confirms presence of a surface erosion on the condyle just posterior to the lateral pole.



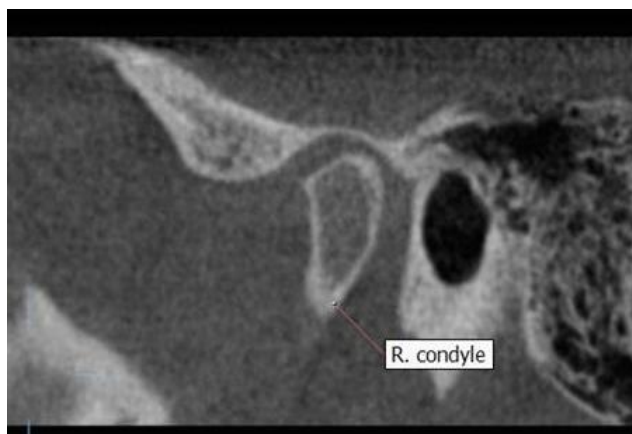
**Figure 4c.** This 3-D color reconstruction also employed a "virtual endoscopy tool" which allowed an even more detailed visualization of this erosion and subcortical defect.

## Condylar comparison

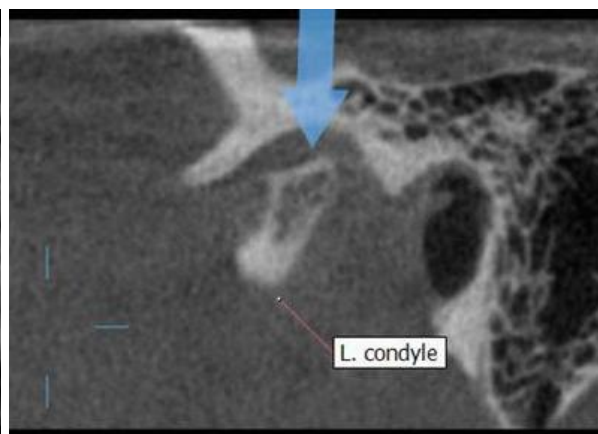
When a patient presents with orofacial pain which the clinician suspects to be related to the temporomandibular joint condyles it is imperative to compare both sides. This is slightly more cumbersome with smaller FOV machines since two views of the condyles are necessary and must be acquired separately. If evaluation of patients with orofacial pain is a large part of the dental practice, a larger FOV CBCT machine may be indicated. A single image acquisition allowing comparison of both sides while evaluating a single volume is probably a more preferable arrangement for this patient population.

It is much easier to compare the condyles in a single multiplanar views or in specialized CBCT temporomandibular joint views as seen in the images below.



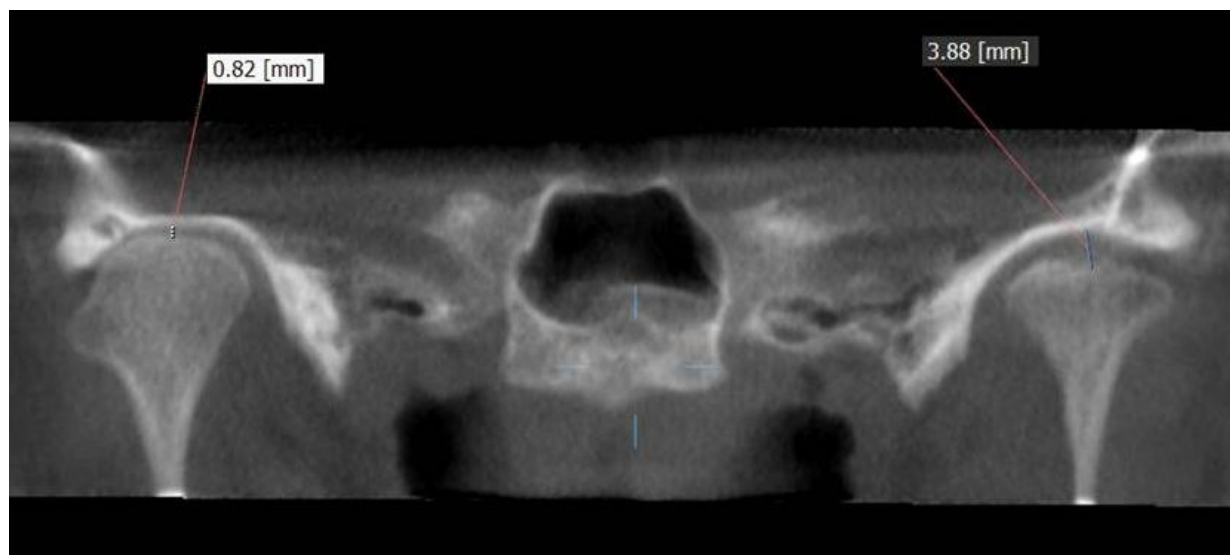


**Figure 5a**

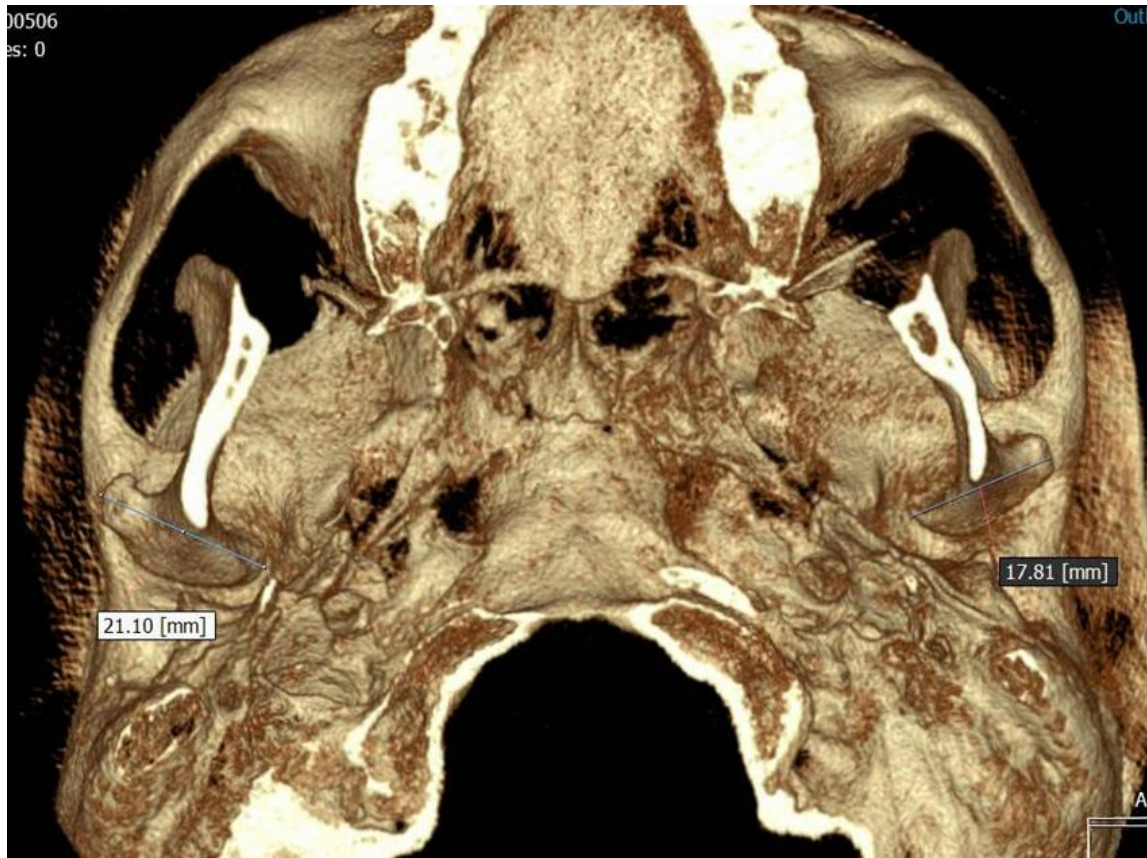


**Figure 5b**

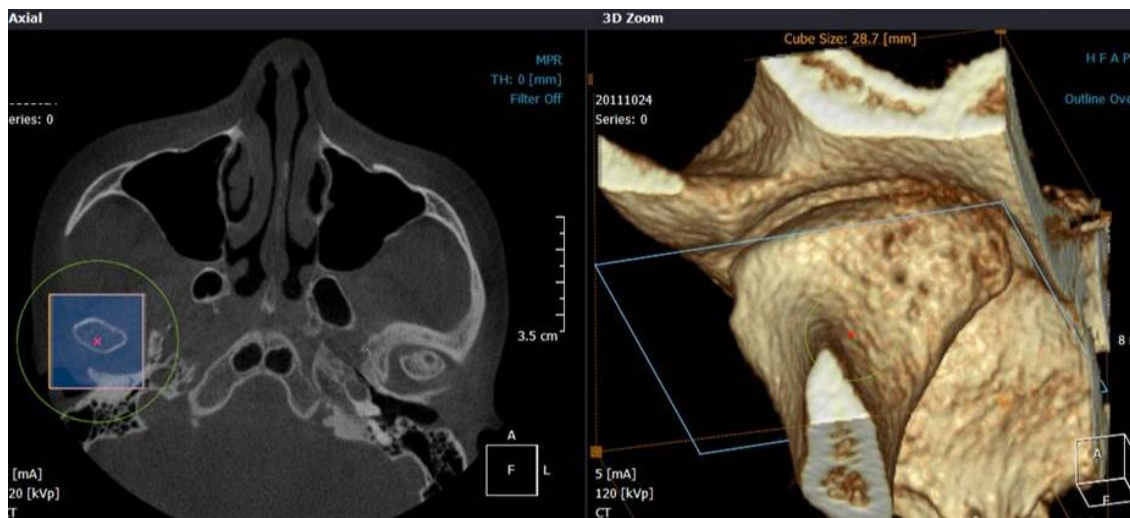
**Figures 5a and 5b.** Thin slice sagittal viewed showing a hypoplastic left condyle relative to the right.



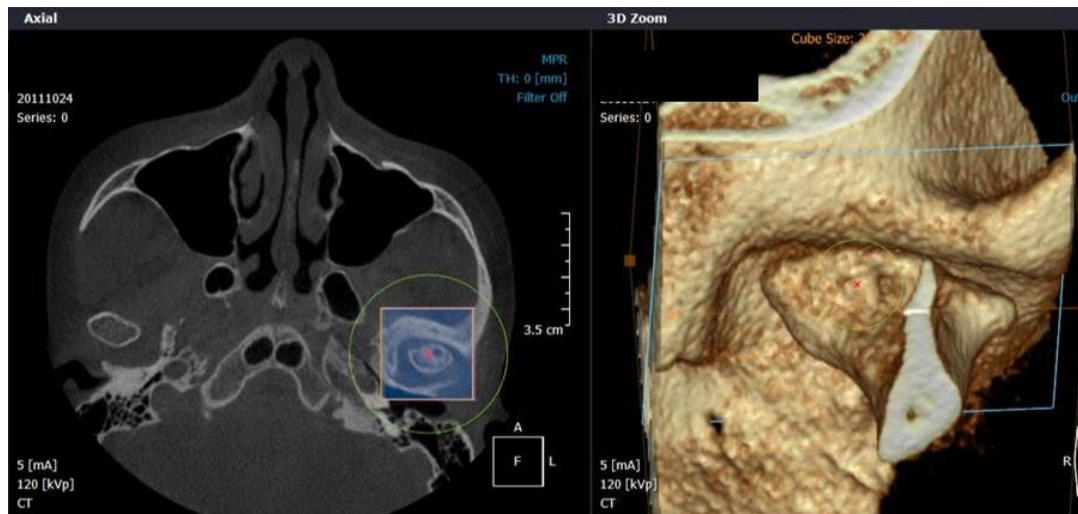
**Figure 5c.** 8.6 mm slice thickness showing hypoplastic left condylar head with a possible surface erosion. There also appears to be less joint space on the right.



**Figure 5d.** 3-D color reconstructed view comparing the condylar heads. This was done in the slice thickness of about 40 mm. Measurements of the condylar with are within 0.1 millimeter accuracy.



**Figure 5e.** 3-D color reconstructed view of another patient's right condyle. Note the subchondral cyst formation and subchondral sclerosis in the left condylar head in the axial slice on the left.



**Figure 5f.** 3-D color reconstructed view of the left condyle of the patient seen in figure 5e. This condyle is obviously remodeled and hypoplastic relative to the right.



**Figure 5g.** 3-D color reconstructed panoramic view showing the hypoplastic left condyle. However, this was only part of the patient's hypoplasia problem, as the ramus is smaller in the posterior sending ramus a shorter. These changes would not be as apparent on a conventional panoramic image. Norwood the patient's periodontal bone loss be as easily assessed.

## **Conclusion**

As you can see from the examples above, and conditions such as osteoarthritis can be easily evaluated and visualized completely with thin gray scale multiplanar images, thickened slice data and 3-D color reconstruction. Almost all pathology can be evaluated or visualized as they really are within the patient. This visualization was unachievable with all previous imaging modalities used in dentistry. In addition we can make our terminology more precise when describing these changes because we can see the condyles in color in 3-D.

More complex situations such as the unilateral condylar hypoplasias seen above can also be easily visualized in easily compared using the many tools and features in third-party CBCT imaging software. If the clinical signs and symptoms warrant a CBCT evaluation of the patient, the clinician will be rewarded by easier visualization of the anatomy and pathology as well as more precise clinical decision-making because of the excellent images available with this imaging modality.



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Dip. ABOM, Dip, ABOMR

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# The good, the bad and the ugly!

**Dale Miles looks at Cone Beam Scanning and poses the questions we all want the answers to**

### Introduction

Nothing in radiology for our dental practices has captured the dentists' attention like cone beam CT technology. Impacting decision-making across almost all dental disciplines and specialties, the adoption of cone beam imaging has grown far faster than digital intraoral or even digital panoramic imaging techniques. This is good for the profession and even better for the patient as dentists and dental specialists now can visualize anatomy and pathology like our medical colleagues. Radiographic 'interpretation' is becoming outdated as we now look at dental problems in 3 planes of section and in 3D color (Figures 1-4). Our patients can actually see their problems in 'life-like' reality instead of peering at gray shadows they don't really understand. Cone beam imaging IS GOOD! The following cases prove this.

On the other hand, the cost of the scan, the increased exposure dose for 'stand-alone' machines and the reticence of third party payers to reimburse dentists for better imaging data from the scans IS BAD!

However, the reluctance of some dentists to review or have reviewed all the data in a cone beam scan is just UGLY!

Why, you ask? I'll give you my opinion as well as present cases to support my opinion.

### Case 1

This 11 year-old white male was referred as part of an orthodontic assessment for cone beam examination because of anterior crowding and an impacted maxillary left permanent canine with retained primary canine. Following radiographic evaluation of this large volume scan, a severe pan-sinusitis was recorded as part of the findings, and the following recommendation made:

'Recommendation: This patient should be referred to his primary care physician and/or an otolaryngologist for clinical and endoscopic examination of the paranasal sinus disease if clinically symptomatic.'

This finding and recommendation is quite commonly made by oral and maxillofacial radiologists as part of the routine and systematic radiographic evaluation of the large cone beam volumes. Would the patient die or be harmed if this were missed by a dentist? Probably not. Can the

treatment of this occult finding, the pan-sinusitis, improve the patient's life? Definitely yes. Is this the way 'healthcare' is supposed to work? Undeniably yes! BUT, before you get too comfortable with my answer to the question of 'will the patient be harmed?', consider the following information below, provided for patients, published online for the American Rhinologic Society by J.M. Dutton, MD1.

### Complications of Sinusitis

1. Intracranial Complications - The frontal, ethmoid and sphenoid sinuses are separated from the intracranial cavity by a layer of bone (Figure 1). If the infection passes through this bone it may infect the tissue and fluid that lines the brain, causing 'meningitis'. In even more severe cases the infection may spread to the brain itself causing an 'abscess', or collection of pus. These problems are life threatening and require prompt and aggressive treatment.
  2. Orbital Complications - The frontal, maxillary, ethmoid and sphenoid sinuses sit immediately above, below, between and behind the eyes, respectively (Figure 2). For this reason, infections of any of the sinuses may spread to the orbit, causing a wide spectrum of complications from mild inflammation of the eyelid to abscesses with possible blindness.
  3. Vascular Complications - The carotid artery and cavernous sinus are two large vascular structures that border the sphenoid sinus. Infections that involve either of these structures may lead to aneurysms or infected blood clots in the intracranial cavity, both of which are potentially fatal.
  4. Asthma - A number of patients suffer from both asthma and chronic sinusitis and, for these individuals, flare-ups of the sinusitis can lead to asthma attacks. Many studies have shown that resolving the sinus condition will result in dramatic improvement of the asthma.
  5. Loss of Smell and Taste - Sinusitis may diminish the senses of smell and taste, since the two are interconnected. This may be either temporary or permanent, depending on the nature of the injury. In most cases, the cause is poor airflow to the olfactory nerve (which detects odors) and by improving the nasal airway the senses of smell and taste improve. This is particularly true in patients who suffer from nasal polyps. However, in some cases chronic sinusitis may permanently injure these nerve endings.
  6. Osteomyelitis - Some recent studies suggest that bone becomes actively involved during a chronic sinus infection, making the infection more difficult to treat. This may even cause the destruction of bone that leads to the intracranial and intraorbital complications discussed above.
- If you are requesting/ordering a cone beam scan that includes the maxillary sinus and there are changes in that airspace, remember that ALL of the paranasal sinus spaces communicate with each other. Even a partial view of the antrum which demonstrates complete opacification mandates review of the remainder of the spaces.

**Dale Miles, BA, DDS, MS, FRCD(C), Diplomate, American Board of Oral and Maxillofacial Radiology.**



Figure 1a: This is an axial view at the level of the condyles demonstrating almost total obstruction of the antral spaces at this level



Figure 1c: A coronal section showing communication of the right antrum inflammation with the right ethmoid air cells



Figure 1b: An axial slice at the mid-orbit level showing opacification of a large portion of the ethmoid air cell complex bilaterally. Fortunately for this patient, the sphenoid sinus region is spared for now

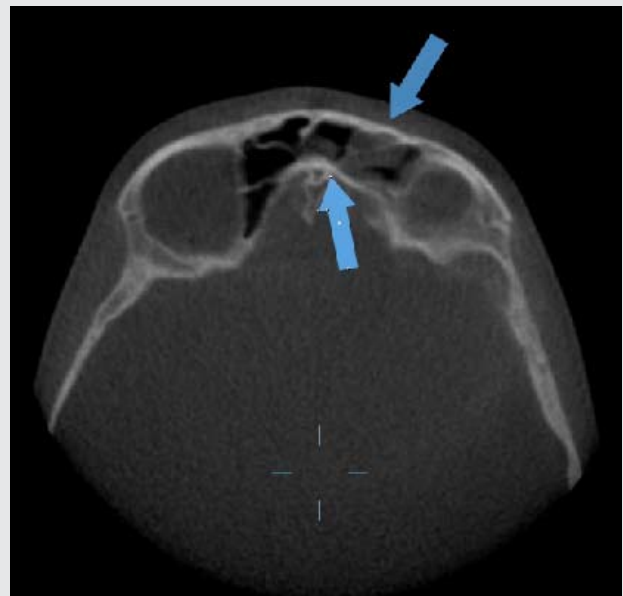


Figure 1d: Frontal sinus involvement



Figure 2: Case 2

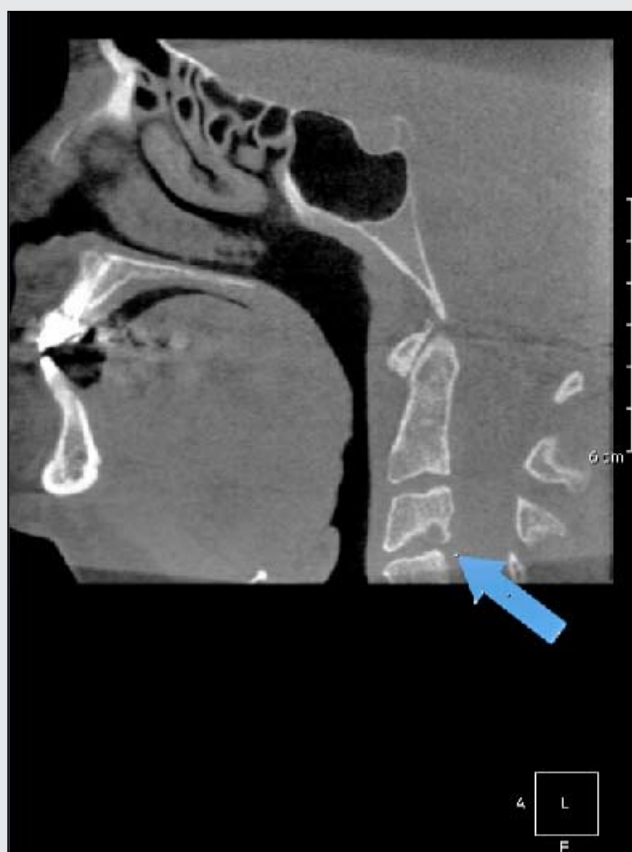
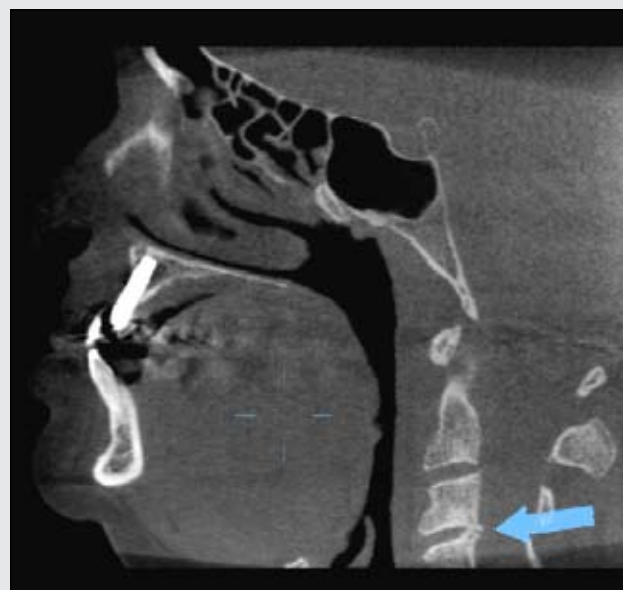
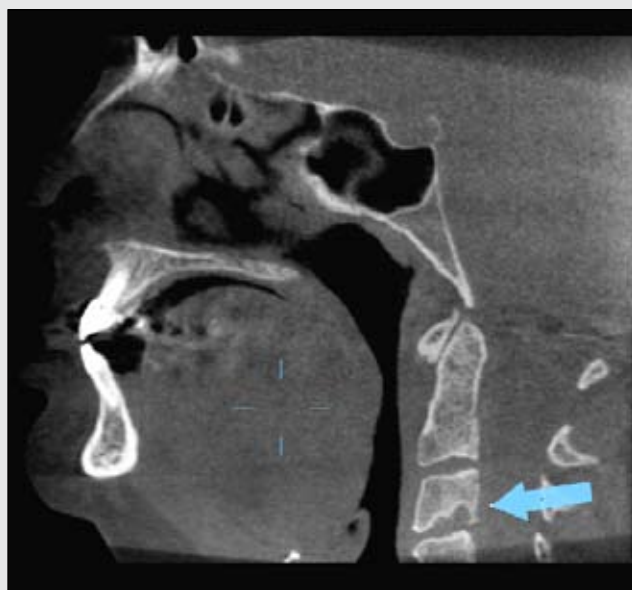
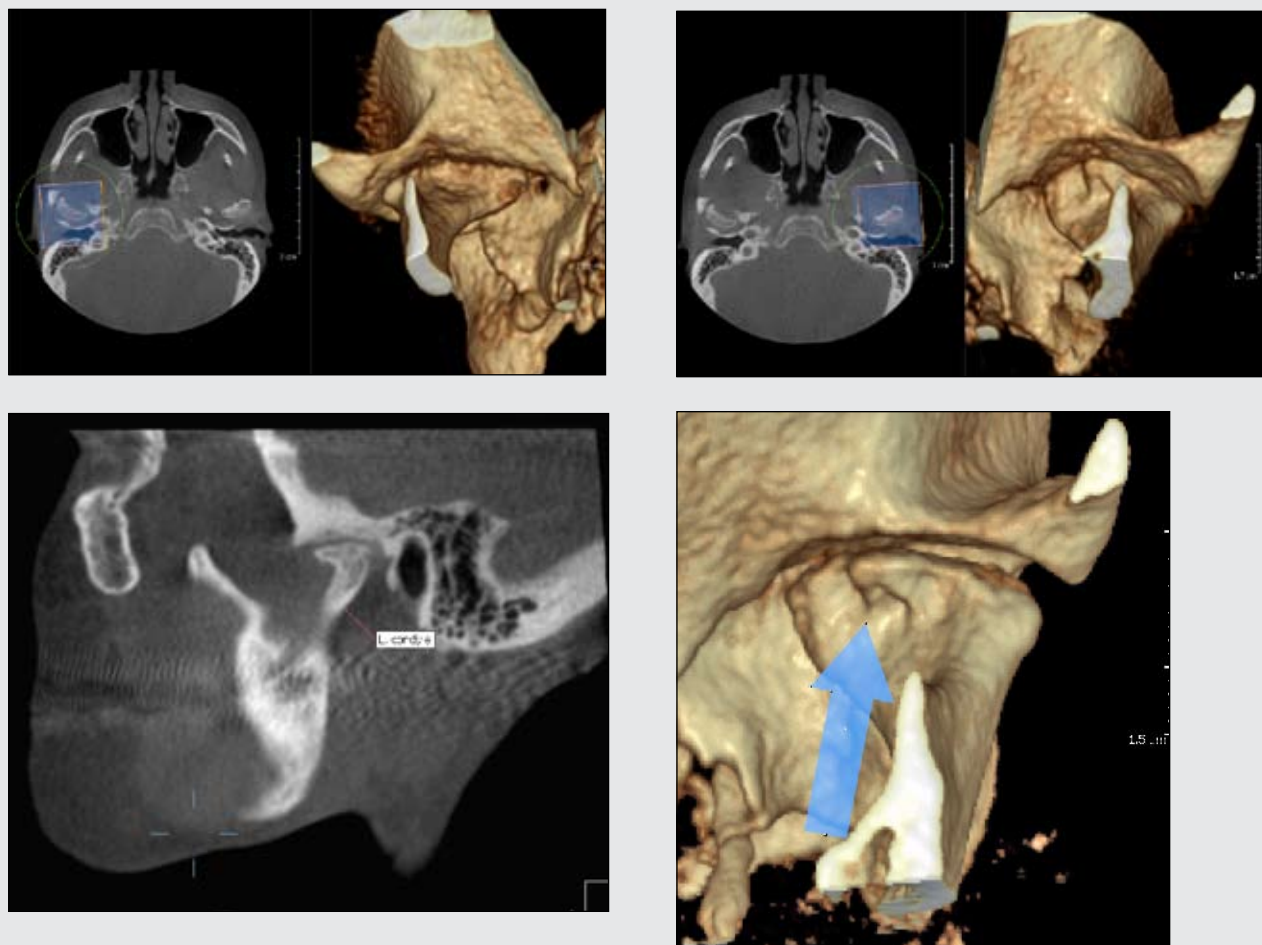


Figure 3: Case 3



## Lack of confidence?

In my humble opinion, dentists have two primary reasons for ignoring the responsibility they incur when ordering or performing a cone beam scan. The first reason is a lack of confidence in their ability to interpret regions in the scan with which they are not familiar. For example, many dentists do not want to be responsible for missing pathology in the following areas:

1. The vertebral column
2. The airway
3. The paranasal sinuses (maxillary, sphenoid and frontal as well as the ethmoids)
4. The nasal cavity
5. Soft tissue structures like muscles, glands, tonsils and adenoids
6. Anything in the 'brain cavity'

Unfortunately for we dentists, teeth do cause sinus symptoms in some cases, sinus problems are NOT restricted to the maxillary sinus in many cases but can involve all of the other spaces as they communicate with each other, osteoarthritis can affect the C-spine and the TMJ condyles simultaneously, and we do get training in soft tissue problems like salivary gland disorders. So, in effect, we dentists ARE responsible for much more than the teeth and gums. There is a patient attached to the tooth! Dentists can acquire sufficient knowledge in cone beam imaging to be able to interpret certainly the limited volume scans of the dental bases. If they are going to employ this technology or the images from it, they should seek additional education about the modality.

The second reason dentists elect to ignore the remainder of the scan outside their region of interest is financial, pure and simple. Some den-

tists do not want to charge the patient 'extra' for an interpretation by a specialist. They feel that this extra fee may reduce the acceptance of the proposed treatment; that is, cost them the revenue for the proposed elective procedure. This reason is absurd and dangerous in my opinion, and borders on malpractice. I, and others, have already addressed this 'position' in other articles.<sup>1,2</sup>

Some dentists think they can have a patient sign a waiver or document refusing to have the scan reviewed to protect themselves from any liability. This practice is indefensible. Patients are not skilled enough in the art and science of dentistry to make the decision to refuse to have the volume read. They cannot diagnose their conditions or potential conditions. If a diagnosis was 'missed' because no one looked at the scan, someone will be liable – the dentist or lab who owns the equipment and performed the image acquisition and the referring dentist or dental specialist who ordered the image(s). Friedland<sup>3</sup> recently cited literature and state law that demonstrated these 'waivers of liability' adopted by dentists 'carries no weight and would be null and void in any legal proceeding'.

Even the major malpractice insurer, Fortress Guardian, who indemnifies members of the American Association of Oral and Maxillofacial Surgery, has written that they will not honor any such waiver<sup>4</sup>. Dentists and dental specialists may have heard that such waivers can be used, information usually delivered by some cone beam company or some 'legal expert' on behalf of the company at a 'manufacture-sponsored cone beam event', and come away thinking they are absolved of any responsibility to look at the entire scan or refer it for professional interpretation. This is a very dangerous position. One which probably WILL be decided in a court of law – and not in favor of the dental professional I'm afraid. **I**





# AAE AND AAOMR JOINT POSITION STATEMENT

*The following statement was prepared by the AAE Special Committee on Cone-Beam-Computed Tomography in conjunction with members of the American Academy of Oral and Maxillofacial Radiography. AAE members may photocopy this position statement for distribution to patients or referring dentists.*

## USE OF CONE-BEAM-COMPUTED TOMOGRAPHY IN ENDODONTICS

### Introduction

The American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology have jointly developed this position statement. It is intended to provide scientifically based guidance to clinicians regarding the use of cone-beam-computed tomography in endodontic treatment as an adjunct to planar imaging. This document will be periodically revised to reflect new evidence.

Endodontic disease adversely affects quality of life and can produce significant morbidity in afflicted patients. Radiography is essential for the successful diagnosis of odontogenic and nonodontogenic pathoses, treatment of the pulp chamber and canals of a compromised tooth, biomechanical instrumentation, evaluation of final canal obturation and assessment of healing.

Until recently, radiographic assessments in endodontic treatment have been limited to intraoral and panoramic radiography. These radiographic technologies provide two-dimensional representations of three-dimensional tissues. If any element of the geometric configuration is compromised, the image can demonstrate errors.<sup>1</sup> In more complex cases, radiographic projections with different beam angulations can allow parallax localization. However, complex anatomy and surrounding structures can make interpretation of planar “shadows” difficult.

### Cone-Beam-Computed Tomography

The advent of CBCT has made it possible to visualize the dentition, the maxillofacial skeleton and the relationship of anatomic structures in three dimensions.<sup>2</sup> Significantly increased use of CBCT is evidenced by a recent Web-based survey of active AAE members in the United States and Canada, which found that 34.2% of 3,844 respondents indicated that they were utilizing CBCT. The most frequent use of CBCT among the respondents was for diagnosis of pathosis, preparation for endodontic treatment or endodontic surgery, and for assistance in the diagnosis of trauma-related injuries.<sup>3</sup>

CBCT, as with any technology, has known limitations. There are also numerous CBCT equipment manufacturers and models available. In general, CBCT can be categorized into large-, medium- and limited-volume units based on the size of their “field of view.”

### Volume Size(s)

The size of the “field of view,” or FOV, describes the scan volume of CBCT machines and is dependent on the detector size and shape, beam projection geometry and the ability to collimate the beam. Beam collimation limits the x-radiation exposure to the region of interest and ensures that an optimal FOV can be selected based on disease presentation. Smaller scan volumes generally produce higher resolution images, and since endodontics relies on detecting disruptions in the periodontal ligament space measuring approximately 200µm, optimal resolution is necessary.<sup>4</sup>

The principal limitation of large FOV cone-beam imaging is the size of the field irradiated. Unless the smallest voxel size is selected in these larger FOV machines, there is also reduced resolution compared to intraoral radiographs or



limited-volume CBCT machines with inherent small voxel sizes. The limited-volume CBCT imaging in endodontics is advantageous, but by irradiating only one site or area, projections acquired may not contain the entire region of interest. Reconstructed images may suffer from truncation artifacts<sup>5</sup> when comparing medical CT with CBCT reconstructed images; medical CT scans provide the most suitable images for tumor-derived alterations due to their capacity for soft tissue visualization.<sup>6</sup>

For most endodontic applications, limited-volume CBCT is preferred over large-volume CBCT for the following reasons:

1. Increased spatial resolution to improve the accuracy of endodontic-specific tasks such as the visualization of small features including accessory canals, root fractures, apical deltas, calcifications, etc.
2. Highest possible spatial resolution that provides a diagnostically acceptable signal-to-noise ratio for the task at hand.
3. Decreased radiation exposure to the patient.
4. Time savings due to smaller volume to be interpreted.

## **Dose Considerations**

Every effort should be made to reduce the effective radiation dose to the patient for endodontic-specific tasks. Using the smallest possible FOV, the smallest voxel size, the lowest mA setting and the shortest exposure time in conjunction with a pulsed exposure mode of acquisition is recommended. If extension of pathology beyond the area surrounding the tooth apices or a multifocal lesion with possible systemic etiology is suspected, and/or a nonendodontic cause for devitalization of the tooth is established clinically, appropriate larger field of view protocols may be employed on a case-by-case basis. Interpretation of the entire acquired volume will be essential to justify the use of task-specific modification of acquisition protocol in such cases.

CBCT has a significant advantage over medical grade CT as radiation doses from commonly used CBCT acquisition protocols are lower by an order of magnitude.<sup>7</sup> Selection of the most appropriate imaging protocol for the diagnostic task at hand is paramount.

## **Patient Selection Criteria**

CBCT must not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. The patient's history and clinical examination must justify the use of CBCT by demonstrating that the benefits to the patient outweigh the potential risks. Clinicians should use CBCT only when the need for imaging cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities.

## **Patient Consent**

Significant risks, benefits and alternatives of special importance should be explained by disclosure and patient education, and then documented in a patient's record. The use of CBCT will expose the patient to ionizing radiation that may pose elevated risks to some patients (*e.g.*, cases of pregnancy, previous treatment with ionizing radiation and younger patients). Patients should be informed that CBCT volumes cannot be relied upon to show soft-tissue lesions unless they have caused changes in hard tissues (teeth and bone), and some of the images may contain artifacts that can make interpretation difficult.

A patient may understand the relevant facts and implications of not following a recommended diagnostic or therapeutic action and still refuse the proposed intervention. This is known as the medico-legal concept of "informed refusal" and is recognized in certain state laws and court decisions.<sup>8</sup> Should a patient be incapable of understanding or responding to an informed consent presentation or be a minor, the informed consent or informed refusal should be documented in the patient's record and signed by an individual legally responsible for the patient.

## **Interpretation**

Clinicians ordering a CBCT are responsible for interpreting the entire image volume, just as they are for any other radiographic image. Any radiograph may demonstrate findings that are significant to the health of the patient. There is no informed consent process that allows the clinician to interpret only a specific area of an image volume. Therefore, the clinician can be liable for a missed diagnosis, even if it is outside his/her area of practice.<sup>9</sup> Any questions by the practitioner regarding image data interpretation should promptly be referred to a specialist in oral and maxillofacial radiology.

## **Protection of Patients and Office Personnel**

At this time, all CBCT equipment produce dose levels and beam energies that are higher than conventional dental radiography, requiring extra practical protection measures for office personnel. Appropriate qualified experts should be consulted prior to and after installation to meet state and federal requirements, and manufacturer's recommended calibration routines should be conducted at the recommended intervals.

## **Recommendations**

The decision to order a CBCT scan must be based on the patient's history and clinical examination, and justified on an individual basis by demonstrating that the benefits to the patient outweigh the potential risks of exposure to X-rays, especially in the case of children or young adults. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities. Initial studies regarding the use of CBCT for a variety of endodontic related imaging tasks have demonstrated the effectiveness and comparability of CBCT to conventional radiography.<sup>10-16</sup> In general, the use of CBCT in endodontics should be limited to the assessment and treatment of complex endodontic conditions such as:

- Identification of potential accessory canals in teeth with suspected complex morphology based on conventional imaging.
- Identification of root canal system anomalies and determination of root curvature.
- Diagnosis of dental periapical pathosis in patients who present with contradictory or nonspecific clinical signs and symptoms, who have poorly localized symptoms associated with an untreated or previously endodontically treated tooth with no evidence of pathosis identified by conventional imaging, and in cases where anatomic superimposition of roots or areas of the maxillofacial skeleton is required to perform task-specific procedures.
- Diagnosis of nonendodontic origin pathosis in order to determine the extent of the lesion and its effect on surrounding structures.
- Intra- or postoperative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal identification and localization of perforations.
- Diagnosis and management of dentoalveolar trauma, especially root fractures, luxation and/or displacement of teeth, and alveolar fractures.
- Localization and differentiation of external from internal root resorption or invasive cervical resorption from other conditions, and the determination of appropriate treatment and prognosis.
- Presurgical case planning to determine the exact location of root apex/apices and to evaluate the proximity of adjacent anatomical structures.
- Dental implant case planning when cross-sectional imaging is deemed essential based on the clinical evaluation of the edentulous ridge.

## **Summary**

All radiographic examinations must be justified on an individual needs basis whereby the benefits to the patient of each exposure must outweigh the risks. In no case may the exposure of patients to X-rays be considered "routine,"

and certainly CBCT examinations should not be done without initially obtaining a thorough medical history and clinical examination. CBCT should be considered an adjunct to two-dimensional imaging in dentistry. Limited field of view CBCT systems can provide images of several teeth from approximately the same radiation dose as two periapical radiographs, and they may provide a dose savings over multiple traditional images in complex cases.

## References

1. Grondahl HG, Huumonen S. Radiographic manifestations of periapical inflammatory lesions. *Endodontic Topics*. 2004; 8:55-67.
2. Pinsky HM, Dyda S, Pinsky RW, Misch KA, Sarament DP. Accuracy of three-dimensional measurements using CBCT. *Dentomaxillofac Radiol*. 2006; 35:410.
3. Dailey B, Mines P, Anderson A, Sweet M. The use of cone beam computer tomography in endodontics: Results of a questionnaire. 2010. AAE Annual Session abstract presentation.
4. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *Int J Dent*. 2009; DOI:1155/2009/634567.
5. Katsumata A, Hirukawa A, Noujeim M, Okumura S, Naitoh M, Fujishita M, *et al*. Image artifact in dental-cone beam CT. *Oral Surg Oral Med Oral Path Oral Radiol Endod*. 2006;101(5):652-7.
6. Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. *Dentomaxillofac Radiol* 2004;33:83-6.
7. Chau ACM and Fung K: Comparison of radiation dose for implant imaging using conventional spiral tomography, computed tomography and cone-beam computed tomography. *Oral Surg Oral Med Oral Path Oral Radiol Endod*. 2009;107(4):559-65.
8. Goodman JM. Protect yourself! Make a plan to obtain informed refusal. *OBG Management*. 2007; 3:45-50.
9. AAOMR executive opinion statement on performing and interpreting diagnostic cone beam technology. 2008
10. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. *J Endod*. 2007; 33(9):1121-32.
11. Lofthag-Hansen S, Huuomogen S, Grondahl K, Grondahl HG. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. *Oral Surg Oral Med Oral Path Oral Radiol Endod*. 2007;103(1):114-9.
12. Cohenca N, Simon JH, Mathur A, Malfaz JM. Clinical indications for digital imaging in dentoalveolar trauma. Part 2: root resorption. *Dent Traumatol*. 2007; 23(2):105-13.
13. Nair MK, Nair UP. Digital and advanced imaging in endodontics: a review. *J Endod*. 2007; 33(1):1-6.
14. Low KMT, Dula K, Bürgin W, von Arx T. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. *J Endod*. 2008; 34(5):557-62.
15. Noujeim M, Prihoda TJ, Langlais R, Nummikoski P. Evaluation of high-resolution cone beam computed tomography in the detection of simulated interradicular bone lesions. *Dentomaxillofac Radiol*. 2009; 38:156-62.
16. Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesslink PR. Detection of vertical root fractures in endodontically treated teeth by cone beam computed tomography scan. *J Endod*. 2009; 35(5):719-22.

