Cone Beam CT

3D Images for 21st Century Dentistry

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The future is now. Next month, at the American Dental Association (ADA) Annual Meeting in San Francisco, Education in the Round (EIR) will debut as the future of interactive dental education. A recent ADA press release describes it as such: "EIR is an interactive, multimedia, learning environment that supplements the need for workshops." The room will serve as a forum for real-time demonstrations that will be projected on eight 61-inch flat screen monitors arranged in a central hub (See bottom of page).

One EIR course, titled "Into the Third Dimension: The Present Future of Dental Care," assured me that our timing for this particular product feature is right on target. The course description reads, "Live patient demonstrations using four of the latest 3-D imaging machines, including the i-CAT from Imaging Sciences International, Galileos by Sirona, NewTom VG by NewTom Dental, and the Iluma from IMTEC Imaging." There are more than 10 cone beam CT (or cone beam volumetric tomography) machines on the market today. When you see that many $150,000-$250,000 machines in the dental market, it's time to take notice. While the price tag is initially a bit of a shock, you must understand the potential of this technology and soon you might add it to your holiday wish list.

Virtually every practicing dentist can benefit from this technology and you do not need to own a machine to benefit. In some communities there are imaging centers that can scan your patient and send the data electronically for your use in office. In other locations, there might be a specialist who has the machine and is willing to scan your patients for a fee. The range of fees for this image varies widely due to location and what is done with the information, but you can expect a range of $250-500. The high end might include planning implants and a reading by a dental radiologist, where the low end might only include the scan and a disk with data on it. There are ADA codes in place for cone beam CT images. [See ADA Codes at right.]

In order to learn more about cone beam imaging and the potential uses of this technology, I contacted six current users. Each person received the same list of questions, and I have presented their answers, edited for length, within this feature. Additionally, we have provided a two-page chart of the machines available with key specifications listed. Since this technology is so new, you can expect changes, updates and new machines in the marketplace. However, if you have the capacity to own a machine, do not wait for the next update, because high-tech items are always getting better and there is never a final model until the item is outdated.

ADA Education in the Round

Photo courtesy of the ADA

ADA Codes

D0360 Cone Beam CT – Craniofacial Data Capture (includes axial, coronal and sagittal data)

D0362 Cone Beam – Two-dimensional image reconstruction using existing data (includes multiple images)

D0363 Cone Beam – Three-dimensional image reconstruction using existing data (includes multiple images)

If you own/use more than one machine, do you use a single software to process all the images? Which software do you use?

Dr. Mah: It is a challenge to create unique images to best visualize the full range of clinical applications that utilize cone beam CT. We use several software packages for different applications. Full-featured packages like inVivo dental (www.anatomage.com) and V-Works (www.cybermed.kr) are the most commonly used at our universities. For orthodontic departments, Dolphin-3D is becoming popular as well (www.dolphinimaging.com).

Dr. Mattia: For initial imaging, we utilize the Interactive i-CAT Zoran and Vision software, then export image data files to external software programs for prosthetic and implant treatment planning. We use SimPlant for interactive 3D surgical and prosthetic implant treatment planning.

continued on page 34

continued from page 32

Dr. Winter: We cater to our referring dentists and customize studies to their specific needs. For this reason, we use multiple types of software. From the outset, we became a SimPlant Master site. This enabled us to convert the NewTom studies into the appropriate version of SimPlant requested by each referring dentist. Many NewTom customers have software keys and receive their studies on a CD or via the Internet so that they can manipulate the images in the NewTom software themselves. In many instances, we deliver the scans in DICOM format so that the dentist can use other proprietary software. The two most common are VIP from Implant Logic Systems and NobelGuide from NobelBiocare. For images generated from i-CATs, we deliver scans using the proprietary software from Imaging Sciences – i-Vision.

How long does it take to prepare the data in a useable format for some typical uses such as Orthodontic 3D ceph, wisdom tooth images, evaluation of a site for implant placement? In other words, the data needs to be manipulated in some way after the image is captured – is that a complex process?

Dr. Gowey: The data manipulates very quickly. A few seconds and a few clicks. The software is very user friendly. 3D reconstructed views take a little longer. The i-CAT software does the data manipulation and presents it in viewable format for you. You can just scroll through the images to see what you are looking for. You can evaluate TMJs much better than a transcranial or sectograph, see the inferior alveolar nerve location for third molar or implant surgery, measure bone thickness, and density. You can also do a 3D reconstruction with a moveable 3D image to allow you to view the area of interest from all directions.

Dr. Langlais: Not a complex process. Ortho we will use Dolphin software but have no experience yet, but our new machine is a large volume. For wisdom teeth, TMJ and implants, we prefer to send out the scan in viewer freeware to the recipient and they do their own studies of the case in their own time.

Dr. Mah: I believe this is the step that is most time- and skill-intensive. I also believe this step is most commonly overlooked by the manufacturers and the new purchasers. While it may take only a couple of minutes to generate a panoramic or lateral cephalogram, it takes time to transfer, open, reformat and save data. Depending on the complexity of the workup this could take anywhere from 20 minutes to more than one hour. Image layout alone is time intensive, but if nerve marking, measurements (including cephalometric analysis) and data segmentation are introduced, the demand on time increases dramatically.

Dr. Mattia: With the i-CAT unit, the system reconstructs and prepares the data for interpretation extremely quickly. Within five minutes the data is ready to interpret with the i-CAT software, so you can begin diagnosis almost immediately with minimal downtime. This is important in our clinical setting. For complex implant treatment planning with external software programs, the i-CAT allows you to export data in the form of DICOM data files, which can then be imported into whatever program the clinician desires (implant planning, orthodontic, etc.). Cone beam CT machines produce a volume of image data referred to as DICOM data files. These files need to be

Dr. Kim Gowey
Profession: Immediate Past President American Academy of Implant Dentistry, Diplomate American Board of Oral Implantology/Implant Dentistry
Location: Medford, Wisconsin
Machines Owned/Used: i-Cat
Scans Taken: "Several hundred"

Dr. Robert Langlais
Profession: UTHSCSA Dental School
Location: San Antonio, Texas
Machines Owned/Used: Morita, Planmeca Romexis, N-Liten Repaots Accurex, E-Film Alphard
Scans Taken: "Several thousand"

Dr. James Mah
Profession: Director of the Redmond Imaging Center, University of Southern California School of Dentistry
Location: Los Angeles, California
Machines Owned/Used: New Tom 9000, i-CAT, Hitachi MercuRay, Iluma
Scans Taken: Approximately 5,000

Dr. Al Mattia
Profession: Practices complete dentistry and oral implantology. Diplomate of the ICOI, member of the Academy of Osseointegration, American Prosthodontic Society, and mentor of the SimPlant Academy.
Location: Boca Raton, Florida
Machines Owned/Used: i-CAT, SimPlant
Scans Taken: More than 400

Dr. Pankaj P. Singh
Profession: Le Visage Cosmetic & Implant Dentistry; Arch Dental Centers
Location: Garden City and New York City, New York
Machines Owned/Used: Sirona Galileos (2)
Scans Taken: 150

Dr. Alan Winter
Profession: President & Chairman i-dontics, LLC
Location: New York, New York
Machines Owned/Used: New Tom 9000, New Tom 3G, i-Cat (10 of them)
Scans Taken: "We have taken approximately 7,500 New Tom images in our Manhattan location and many thousands more in our other centers located in New York, New Jersey, Georgia, and Florida."

continued on page 36

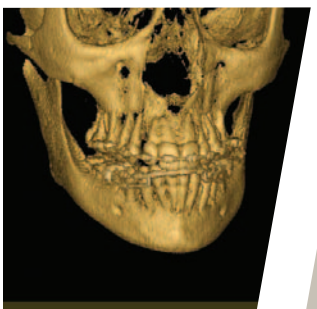
continued from page 34

"reformatted" so the volume of data can be read by an external planning software program. External software programs can be self-reformatting, or require an external site reformat the data for a fee. Programs that self-reformat the DICOM data are preferred as the doctor can load the patient DICOM data from the cone beam CT and begin planning immediately. Softwares that are not self-reformatting are less expensive and logistically cumbersome with respect to patient time and appointment management, plus the additional fees and third-party involvement.

Is it better to have the machines in a specialist's office or free-standing facility? Why?

Dr. Gowey: I am a general dentist and have the machine in my office. The convenience factor is very important. You can take the scan at the exam appointment and review findings immediately. You can take post-op scans after surgery. Patients appreciate the convenience of having this in your office.

Dr. Mah: I can't say it is better one way or another, but rather it is the time commitment and skill of the operator to generate the best images to represent the clinical problem. This



An example of a 3D hard tissue view rendered from a scan of a patient during orthodontic treatment.

Photo courtesy of NewTom Dental

A Cone Beam Comparison Chart

				
Manufacturer	Belmont	Cefla Dental Group	Imaging Sciences Int'l	Imaging Sciences Int'l
Machine name	**Alphard 3030**	**MyRay SkyView**	**i-CAT**	**i-CAT (next generation)**
Gray scale	8 Bit and 14 Bit	12 Bit	14 Bit	14 Bit
Footprint (in inches unless otherwise noted)		150 x 240 cm	H 72 x W 44.2 x D 58.7	< 30 sq. ft.
Image detector	CsI Flat Panel	Dual field Image Intensifier with Digital CCD camera 1000x1000	Amorphous Silicon Flat Panel	Amorphous Silicon Flat Panel
Patient positioning	Seated	Supine	Seated	Seated
Scan time	17 sec.	10/15/20 sec.	10 - 40 sec.	5, 8.5 or 26 sec.
Scan height (in inches unless otherwise noted)		6	9.8 - 12	4, 6, 8, 10, 13 cm
Scan diameter (in inches unless otherwise noted)		11 x 11 x 11 cm	7.9 x 9.8	16 cm
Slice thickness		.5 mm	0.2 - 0.4 mm	.12 - .4 mm
Cephalometrics	Yes		9 in., 12 in. with opt. $25K software, 2nd scan	17 cm height/ 23 cm diameter
Pre-installed software	Alphard 3030		Xoran Cat	
List	Coming to market 4th quarter 2007		$170,000	
Web site	belmontequip.com	cefladentale.it/ index2.html	imaging sciences.com	imaging sciences.com

						
J. Morita	Kodak/Imtec	NewTom Dental	NewTom Dental	Planmeca	Sirona	TeraRecon, Inc.
3D Accuitomo	**Iluma**	**NewTom 3G**	**NewTom VG**	**Promax CBVT 3D**	**Galileos**	**PreXion 3D**
8 Bit	14 Bit	12 Bit	14 Bit	12 Bit	12 Bit	12 - 16 Bit
H 82 x W 64 x D 48	H 83 x W 42 x D 55	H 65 x W 75 x D 99	H 91 x W 43 x D 57	H 96 x W 33+ x D 49.5	H 79 x W 63 x D 63	H 79 x W 59 x D 39
Image Intensifier CCD	Amorphous Silicon Flat Panel	Image Intensifier CCD	Amorphous Silicon Flat Panel	CMOS Flat Panel	Image Intensifier CCD	CsI Flat Panel
Seated	Seated	Supine	Standing/sitting	Standing/sitting	Standing/sitting	Seated
18 sec.	20 - 40 sec.	36 sec. or less	20 sec.	18 sec.	14 sec.	19 sec. - 37 sec.
1.57 - 2.36	10.4 x 12.2	6 - 12	9.84	1.97 - 3.15	6	3
1.57 - 2.36	up to 7.4 x 9.4 cylindrical	9.8	7.87 x 9.84	1 x 1.16, 2 x 3, 3.1 x 3.1	6 x 6 x 6	3.2
0.125 - 2.0 mm	0.09 - 0.4 mm	0.1 - 0.5 mm	0.1 - 0.5 mm		0.15 - 0.3 mm	.007 mm
No	9 in. Ceph	Yes, 12 in. sensor	9.8 in. Ceph	with Digital Ceph attachment, no 3D	6 in. Ceph	
I-Dixel	Iluma Vision 3D	NewTom 3G	NewTom VG	N-Liten 3D	Galaxis 3D	
$252,000		$189,000-$229,000	$170,000	$200,000 new, $150,000 upgrade	$200,000	$149,000
jmorita.com	kodakdental.com	newtomdental.com	newtomdental.com	planmeca.com	sirona.com	rtviz.com

continued on page 38

continued from page 37

is perhaps where the imaging centers have an advantage because they have the advantages of patient diversity and individuals performing highly technical tasks repetitively, allowing for unique skill development.

Dr. Mattia: Optimally, from a patient flow and management perspective, having an i-CAT unit in your office is the ideal situation. The data is accurate, consistent and timely, so you can begin interpretation and patient consultation without having to reappoint the patient or involve a third party. The i-CAT allows you to control all of the variables with respect to patient diagnosis, data control, and timing. You, of course, need to have the volume of patients needing these services to make practical sense of the investment. Otherwise, a dental imaging center is the next best choice for utilizing cone beam CT.

How would you suggest a potential owner of this technology go about selecting a machine? What are the first, second, third, etc. items to consider in order of importance?

Dr. Gowey: Talk to or visit several owners of the machine you are considering to make sure it will be right for you. Make sure the field of view will be large enough for what you want to use it for. Some of the machines have a limited field of view and can't be used for orthodontic 3D cephalometrics. If you are doing implants, you would like both full jaws in the same image. If you are interested in imaging TMJ's make sure this can be done easily. I would also look at warranty and upgradability. What is covered in the maintenance contract? These are expensive pieces of equipment and you do not want it to become obsolete when the software upgrades.

Dr. Langlais: There are many items to consider:

- Get a machine that is very easy to use.
- Get a machine that also does other functions such as pano this helps to pay for the machine especially a pan that does bite wings, periapicals and ceph as well as cone beam CT.
- Get a small volume; this has smaller files, faster processing, better resolution and less medical risk for not seeing disease in a strange part of the larger volume.
- Get easy software but with all the tools.
- Make certain there is a bridge to the office management software.
- Make certain the manufacturer has telephone tech and technique advice.
- Get more than one opinion before buying.

Dr. Mah:

- Get educated – Attend meetings, read articles, talk to cone beam CT owners, listen to marketers with an educated view.
- Develop a business plan – Which type of patient will be imaged? This will determine the required field of view and corresponding costs of suitable devices. Patients for dental implants may not need the same field of view as orthodontic patients. How many patients will be imaged? Where will the device be placed? Will there be leasehold improvements that require lead shielding? What are the real costs of ownership?
- Staff training – Who will be the operator? What will it take to train the operator? Who and how will data be transferred and archived? How will this new diagnostic device change the current workflow of patient care?
- Constant improvement of process – There will definitely be a learning curve with software utilization. In addition software packages will continue to improve as well as the hardware itself. What are the checks and balances for quality?

Dr. Mattia:

- Sensor design: There are big differences in the quality and amount of imaging data that cone beam CT machines provide, directly related to the imaging sensor design. There are basically three different types of sensors: CCD, CCD-image intensifier, and flat panel. Flat panel sensors, like the i-CAT unit use, provide the best combination of image quality and size, which have the most clinical significance in dental diagnosis.
- Unit requirements: There is a lot of difference between cone beam CT units with respect to the actual space they require to operate.
- Unit data work flow: cone beam CT units differ greatly in the time it takes to get working diagnostic images.
- Data storage and networking requirements: Different cone beam CT units have different data file sizes and networking requirements.
- Unit history and experience: Another important consideration would be the history, development and clinical experience of the cone beam CT unit and its track record in clinical practice over time.

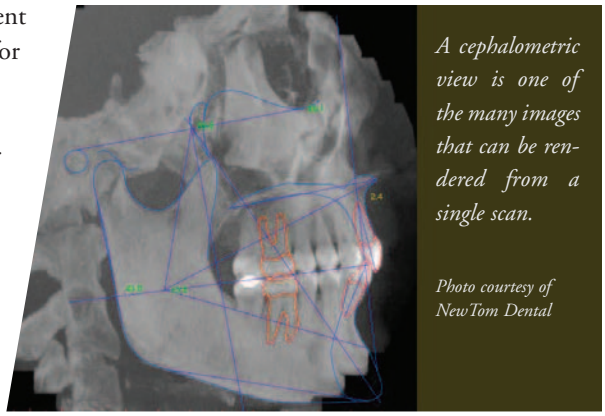
Dr. Winter: I would suggest a potential purchaser to consider the following:

- What is the footprint of the machine? Do you have the adequate space for the machine without losing an existing operatory? The latter is important because I would discourage dismantling a usable operatory just to accommodate a cone beam CT scanner. While it is convenient to have the machine in the office, a partially used operatory will generate more income for any dentist than a scanner will. Remember, if you don't have a scanner, someone close by does. While it may not be as convenient as it in your own office, you do not want to lose revenue unnecessarily.
- Understand the technology of how the scan is acquired and what are the repair costs if this high-priced portion of the scanner breaks.
- Ask about the frequency of problems with a scanner. Have they just introduced new technology that still has bugs to be worked out? Is the existing system tried and true and works without many hitches? If you buy a machine, when does the company intend to release new software or hardware after you "own" it? Will these be retrofitted to the machine you are about to buy? Will they be included in your first year's warranty? Are there any hidden costs that you should know about?

continued on page 40

continued from page 38

- Does the proprietary software that comes with the scanner have treatment planning capabilities or will you need to get special application software for pre-surgical analysis?
- What is the annual maintenance fee for the scanner?
- If the machine breaks down and cannot be fixed by troubleshooting over the phone or via the Internet, how quickly can a technician get to your office to repair it?
- How many other machines has the company sold of the particular unit you are exploring? What is the track record? Call a couple of dentists who have the machine to learn from their firsthand experiences and whether the machine and the company performances are everything the sales rep claims them to be.
- Does the company manufacturing the machine have "staying" power? Will they be around when you need them?



A cephalometric view is one of the many images that can be rendered from a single scan.

Photo courtesy of NewTom Dental

Which size field of view do you use most often?

Dr. Gowey: We usually use a full field of view, which goes from the frontal sinus to the inferior border of the mandible. Occasionally we will take a high resolution image of the maxilla or mandible, especially if we are looking for a problem with an endodontically treated tooth or infection.

Dr. Langlais: All of our scans are small volume but that will soon change as we are getting a bigger machine.

Dr. Winter: We use the nine-inch field most of the time. This enables us to easily capture everything we want on the NewTom scanner.

How could this technology or software improve?

Dr. Langlais:

- Technology will eventually create better soft tissue imaging.
- Big variety and variations in dose between machine brands.
- The software needs simplification in many instances.
- More specific applications such as implants or surgical guides with each software not a special software for each application like Simplant for implants and dolphin for ortho.
- Free viewer software should be a part of each software to send out the scans to referral parties.

Dr. Mah: Since cone beam CT is relatively new, there is vast room for improvement in many areas. Improvements could include higher resolution, better contrast, faster scans to reduce motion artifacts, improved patient restraining devices (head holders), improved patient alignment methods, faster reconstructions, smaller file sizes, better data visualization in 3D, improved software tools for clinical measurements, features for implant planning and surgical simulation.

Dr. Mattia: I think the software side of the technology holds the potential for bringing cone beam CT into mainstream restorative dentistry.

Dr. Singh: This technology could be improved by improving the software to reduce scatter or noise, thereby improving the quality of the image being viewed. Also, if the software could be manipulated to view soft tissue like an MRI, that would improve the diagnostic ability of the technology.

Which specialists are using cone beam CT the most: periodontists, oral surgeons or orthodontists?

Dr. Mah: I believe that most cone beam CT is being used by individuals placing implants. This group is followed by orthodontists.

Dr. Winter: In my opinion, periodontists, hands down, are using cone beam CT images the most. There are some periodontists that use it for every single implant case they do.

Which patient position do you prefer for these images (seating, standing, lying down)? Why?

Dr. Gowey: Seated is the simplest. The machine doesn't take up as much floor space as one in which you lie down. If you sedate patients, they are not able to stand for a post-op scan. You want them to be able to hold still and seated is most convenient for the patient.

Dr. Mah: I prefer seating for reasons related to patient stabilization. The footprint of these devices is smaller than a lying down device. Although individuals who study sleep apnea might prefer a lying-down orientation.

Dr. Singh: I prefer the time-tested standing position that most patients feel comfortable with and are used to, as they are already familiar with the Panorex model of taking extraoral images.

Dr. Winter: I only have experience with patients lying down or being seated. Each has its advantages and disadvantages. We have virtually no problems with patients lying down. Patients rarely move, the scans are clear, and rarely do we need to take a scan over. Claustrophobia is not an issue with the NewTom. Most patients are able to have scans in the seated position as well, but we do have problems with exceptionally large patients. Sometimes, the arm of the scanner cannot negotiate around their backs. With their chins fixed in place, movement is usually not an issue with sit-down scanners. My only concern with

continued on page 42

continued from page 40

standing units centers around patient shifting their weight or in the case of a large patient, not being able to negotiate around his or her back.

What is the future for this technology?

Dr. Gowey: This technology is so useful for diagnostic purposes that it will become very commonplace in the future. Once you have used cone beam CT, you will never go back to using just a panoramic film.

Dr. Langlais: Huge! This is just the beginning of a whole new era of dentistry much like the high-speed handpeice was in circa 1950.

Dr. Mah: The future is indeed now. I believe cone beam CT in dentistry will parallel the imprint that medical CT had in medicine. Dentistry is following a parallel trend, albeit 30 years later. I believe that in the next 10 years, it will be the standard of care for most complex dental procedures much like CT imaging is in medicine.

Dr. Singh: The future of this technology is to be able to view both hard and soft tissues and also be able to perform risk assessment for osteoporosis by doing a bone density evaluation. Also if the software came with a database of pathologies so that it can scan for these and highlight them for the user to see, i.e.: impactions, nerve mapping, osteouryelitis, etc.

Dr. Winter: The future of this technology is extremely promising. It is on the verge of widespread acceptance and use as the standard of care in dental radiography. Its use will become absolutely normative for dental implants, impactions sitting on the mandibular nerve, and more. TMD specialists and dentists treating sleep apnea are using this technology with greater frequency, and endodontists are beginning to use 3-D imaging for complex endodontic problems.

Closing Comments

Dr. Langlais:

- Having the patient sign a release absolving the doctor from detecting disease won't hold water in court.
- Reporting services are available such as from the Advanced Dental Board info can be found at Learn Digital.com.
- Doctors are advised to take a course on cone beam CT before getting into it to really learn more about the technology. Universities offer such courses as well as local organizations & meetings.
- The least worrisome avenue to the affordability of a cone beam CT machine is one that the doctor can use for pans, bitewings, periapicals and ceph functions as well as cone beam CT.

Dr. Mah: Cone beam CT is a novel and disruptive technology in dentistry and for a fairly traditional profession there is apprehension. These include cost of the technology, computers, radiation exposure, education and issues related to responsibility for the data. For many, these have proven to be barriers to adoption. While these barriers exist, they can all be justified and accounted for. I believe the key is education in both dental schools and in continuing education programs. Here applications of cone beam CT can be discussed in the overall context of the risks and benefits of patient care.

Dr. Mattia: I believe that the application of cone beam CT is the most significant development in dentistry since the endosseous implant work of Branemark. As a student of Peter Dawson, I learned the importance of a thorough and detailed diagnostic examination as the cornerstone of high quality patient care. As more and more of our fellow clinicians experience the wealth of diagnostic information this technology provides, I see cone beam CT and 3D interactive diagnostic interpretation becoming foundation of the "Millenium Dental Examination," and the standard of care for dentistry.

Dr. Winter: There are other advantages to cone beam CT technology that dentists need to be aware of. The first, and most important, has to do with the reduced radiation used by these machines. When compared to all medical CT scanners, all other cone beam CT units use comparatively little radiation. As dental health care professionals, we have an obligation to use the least about radiation to diagnoses and treat patients. The other issue that needs to be addressed is that due to the physics of a cone beam CT scanner, their images – from all manufacturers – is 10 times more accurate than those form a medical scanner. ■