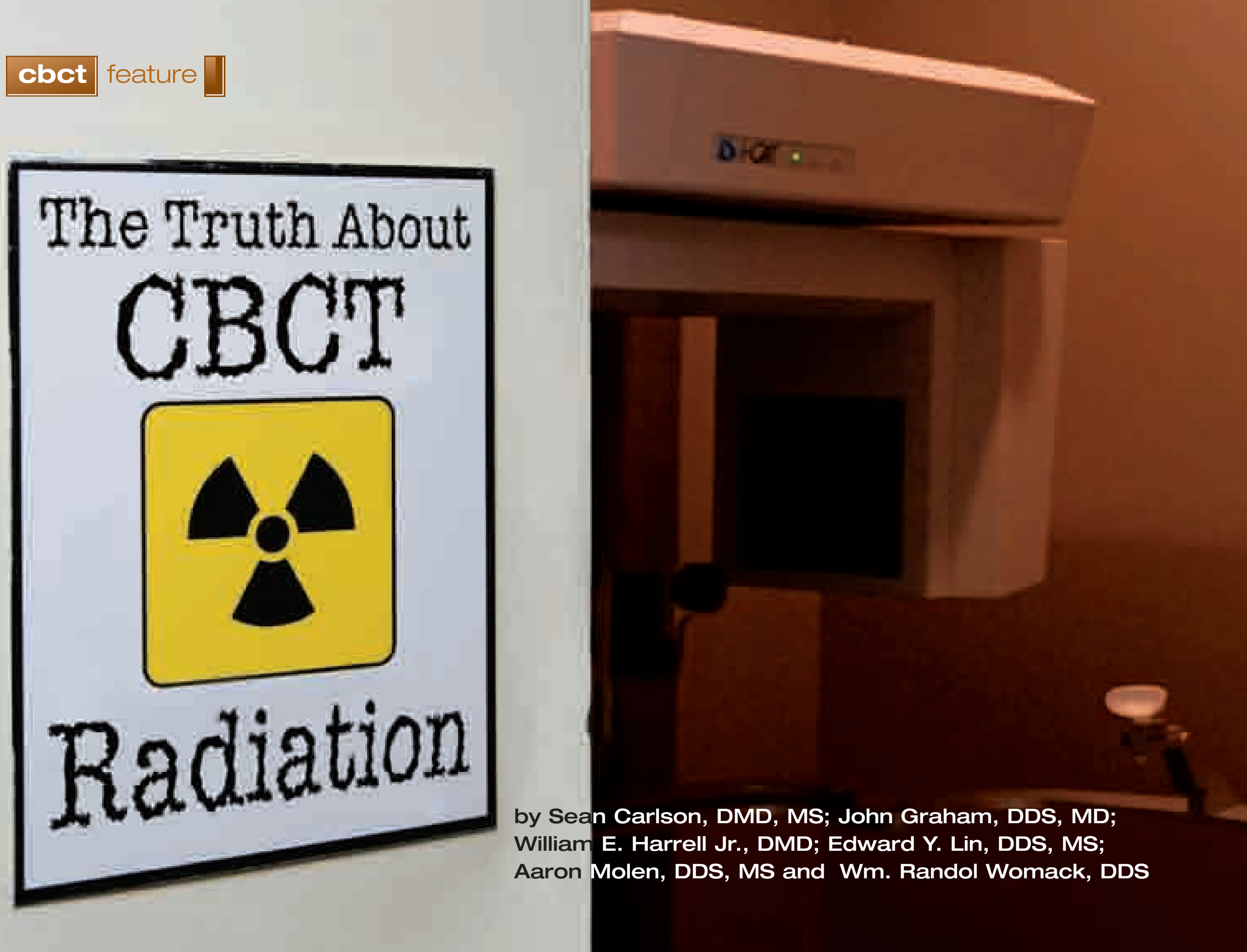

by Sean Carlson, DMD, MS; John Graham, DDS, MD; William E. Harrell Jr., DMD; Edward Y. Lin, DDS, MS; Aaron Molen, DDS, MS and Wm. Randol Womack, DDS

A general consensus in dentistry exists, at the present time (2011), that the revolutionary technology known as cone beam computed tomography (CBCT), aka, cone beam volumetric tomography (CVCT), has the potential to significantly improve diagnosis, treatment planning, treatment monitoring and treatment outcomes in many dental procedures. The clarity and detail provided by the volumetric images enables a doctor to maximize the effectiveness and efficiency of the treatment they can provide to a patient.

Orthotown Magazine has published multiple articles by leading practitioners about the advantages CBCT has provided in their practices. The proliferation of CBCT imaging devices during the past five to 10 years is evident of the interest in and adoption of the undisputed, tangible benefits of the information gained through a few seconds of scan time.

There currently exists significant confusion with respect to the ionizing radiation produced during a scan. Many articles and consumer publications have reported widely varied and often incorrect and/or distorted data about the radiation values and risks from modern digital imaging devices being sold to and utilized in dental practices and dental specialties. This has led to apprehension from patients and has left the doctor with indecision as to how to effectively evaluate this technology and how to answer questions that are posed when CBCT scans are recommended and/or utilized in their practice.

Before beginning any discussion on dosimetry, we must first become familiar with the International Committee of Radiological Protection (ICRP). The ICRP is a group that is designed to protect and inform the public regarding the harmful effects of ionizing radiation. They set guidelines for the medical and dental communities to help minimize the risks to the public. In 2007, the ICRP released a set of updated guidelines on the limits of X-ray exposure. The two most important take-home messages from this set of guidelines are: 1. Non-occupational exposure to ionizing radiation should be limited to 1,000µSv per year and 2. A revised set of tissue weightings (released as part of the 2007 guidelines) should be used when calculating effective dose of ionizing radiation.

Using these guidelines from the ICRP, as clinicians, we can simply gauge our diagnostic X-rays to make sure we stay at or below the guidelines. Therefore, if we minimize our patients' total exposures to less than 1,000µSv per year, we are well within the "safety zone" as judged by the ICRP.

The following graphs are a good start in defining what is accurate and true about ionizing radiation from CBCT scans understanding that the ALARA principle (As Low As Reasonably Achievable) is always the goal whether it be 2D or 3D imaging.

Recent publications by Ludlow and colleagues comprehensively describe the X-ray exposure of the most common dental X-rays. These exposure values can be seen in Tables 1 and 2. Notice that for an FMX using round cone collimation, the effective dose is 170.7µSv verses FMX using rectangular collimation is 34.9µSv. The exposure for a ProMax panoramic X-ray is 24.3µSv. The exposure for a lateral cephalometric X-ray is 5.6µSv.

Table 2 shows the exposure values for CBCT X-rays. In orthodontics, it can be argued that one of the more common

Table 1: Effective dose for commonly used dental radiographic examinations
Comparison of International Commission on Radiological Protection (ICRP) methods from 1990* and 2007.†

Type of Examination	Effective Dose (Microsieverts) ICRP 1990 Tissue Weights	ICRP 2007 Tissue Weights	Change in Effective Dose 1990-2007 (%)
FMX‡ with PSP§ or F-Speed Film and Rectangular Collimation	12.2	34.9	186
BW¶ with PSP or F-Speed Film and Rectangular Collimation	1.0	5.0	422
FMX with PSP or F-Speed Film and Round Cone	58.4	170.7	192
FMX with D-Speed Film and Round Cone#	133	388	192
Panoramic Orthophos XG** (CCD††)	4.3	14.2	231
Panoramic ProMax‡‡ (CCD)	7.1	24.3	241
Posteroanterior Cephalometric (PSP)	3.9	5.1	32
Lateral Cephalometric (PSP)	3.7	5.6	51

• Source: International Commission on Radiological Protection.[1]
† Source: Valentin.[3]
‡ FMX: Full-mouth radiographs.
§ PSP: Photo-stimulable phosphor.
¶ BW: Bitewing
†† OCD: Charge-coupled device
# Calculated as F-speed film value x 2.3 (See Ludlow and colleagues[5]).
** Orthophos XG is manufactured by Sirona Group, Bensheim, Germany.
‡‡ ProMax is manufactured by Planmeca, Helsinki, Finland.

Table 2: Effective dose from dento-alveolar and maxillofacial radiographic examination for CBCT and MDCT devices. **Comparison of ICRP 1990 and 2007 calculations**

Technique	Effective Dose, µSv, ICRP 1990 Tissue Weights	Effective Dose, µSv, ICRP 2007 Tissue Weights	Change in Effective Dose 1990-2007
Large FOV			
New Tom3G large FOV[4]	42	68	62%
CB Mercuray facial FOV maximum quality[4]	806	1073	33%
CB Mercuray facial FOV standard quality[4]	464	569	23%
Next Generation i-CAT portrait mode	37	74	100%
Iluma standard	50	98	97%
Iluma ultra	252	498	97%
Average			61%
Medium FOV			
CB Mercuray panoramic FOV[4]	264	560	112%
Classic i-CAT standard scan	29	69	137%
Next Generation i-CAT landscape mode	36	87	139%
Galileos default exposure	28	70	148%
Galileos maximum exposure	52	128	148%
Somaton 64 MDCT	453	860	90%
Somaton 64 MDCT w/ CARE Dose 4D	285	534	87%
Average			123%
Small FOV			
CB Mercurayl FOV maxillary[4]	156	407	161%
ProMax 3D small adult	151	488	224%
ProMax 3D large adult	203	652	222%
PreXion 3D standard exposure	66	189	187%
PreXion 3D high exposure	154	388	151%
Average			189%

ICRP, International Commission on Radiological Protection.
4. Previously published data.

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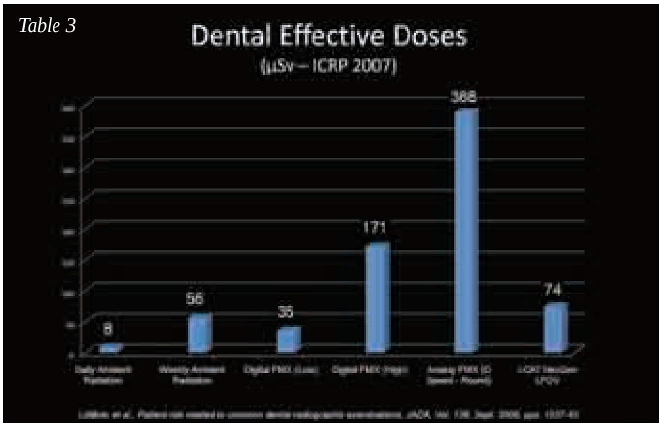
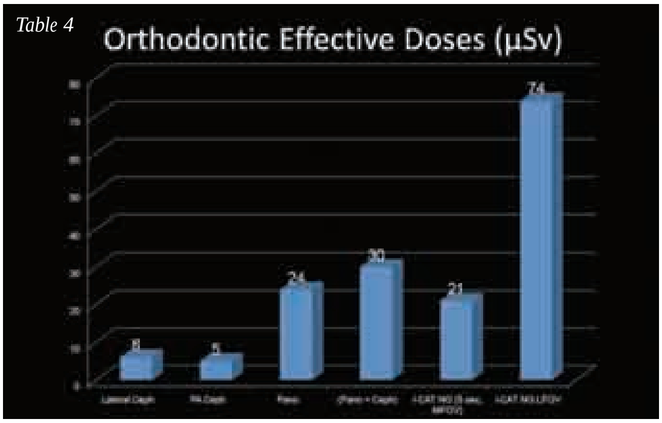


Table 3



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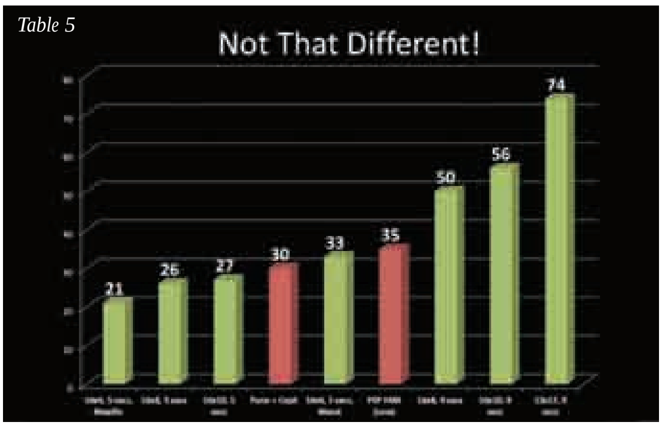

Table 5

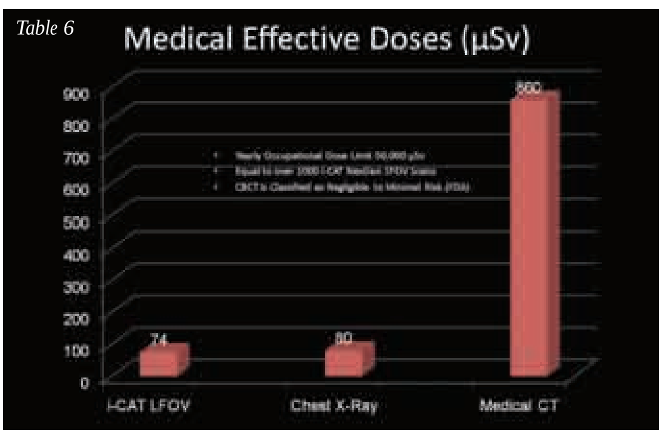

Table 6

CBCT X-rays is a large FOV (LFOV) scan (17-23cm at .3 voxel resolution) using the Next-Generation i-CAT machine. Notice that the effective dose for this type of scan is 74µSv. Medium FOV (MFOV) is usually around 13cm height and smaller FOV, i.e. 4, 6, 8cm height (SFOV) or "focused field of views" (FFOV) can be done to reduce the exposure time and the size of the region of interest.

All of the X-rays mentioned above fall well below the guideline limits of X-ray exposure as set by the ICRP. Recall that the limit of 1,000µSv indicates that we are well within the "safe zone" for X-ray exposure if we stay below this. However, the "safe zone" is really the issue we must debate.

Discussing the "safe zone" in dental X-rays is where emotions run high. We must somehow be able to put this in perspective based on ionizing radiation exposure from other sources. The best way to put this in perspective is by using background radiation exposure data. This data has been well researched. Background radiation exposure in the United States is approximately 8µSv per day. Therefore, when we discuss the "safety zone," or the risk of X-ray exposure, it helps to compare it with our daily exposure of 8µSv per day or 2,920µSv per year, which is the base line for human daily exposure on the earth.

When we compare the dosimetry used in dentistry today with the daily background exposure value of 8µSv or 56µSv weekly, it becomes evident that some of the dental X-rays being used today – with no real concern about exposure by the public or the dentist – are much higher than a LFOV CBCT scan (see Table 3).

Within the specialty of orthodontics, the options for X-rays show a variety of combinations that will provide the orthodontist with the diagnostic information needed to plan treatment for his patient are shown in Table 4. What is not indicated on the graph is the "quantity of information" provided by the different options for X-ray choices… but that is a different article.

Today's CBCT machines offer a wide variety of settings and fields of view, which enable the orthodontist to decide the best and most conservative X-ray option for each individual patient. Table 5 shows not only the comparative options for CBCT scans, but it also includes the routine pan/ceph and FMX exposure in µSv.

Another comparison – often confused by the public because of the terms "CAT scan" or "CT scan" – is the fact that a dental CBCT scan is not the same as a medical CT scan in terms of the ionizing radiation given to the patient. Table 6 shows the difference in exposure of two common medical X-rays compared to the dental CBCT scan.

There is an active effort being made by machine manufactures to provide settings that will offer the clinician the best options for choosing the appropriate CBCT scan for each diagnostic evaluation. Table 7 presents the latest information comparing the newest scan time and newest FOV selections for a CBCT scan compared to the commonly used pan/ceph diagnostic radiographs.**

Figure 1 is an image that demonstrates the type of quality that can be achieved using only the five seconds, low-dose scan taken at 0.3mm voxels and with a FOV of 10x16cm.

Again, it is important to understand that patients are not only exposed to clinical radiation but also they, and everyone on the planet, are exposed to "background" radiation each day. To reiterate, the United States background radiation dose is 8.0µSv per day. We understand that radiation accumulates over time and elective clinical radiation adds to the patient total. However, when the ICRP's non-occupational exposure limit is 1,000µSv per year, which is far less than what a person would naturally get in a year, it is clear that the ICRP has set its limit very low. Yet this limit does give patients and parents a defined margin, yearly, to measure the accumulative exposure to all types of non-occupational radiation in order to stay in the "safe zone." It also gives clinicians a parameter in determining the "safe zone" of accumulating radiation for a patient during orthodontic treatment or observation.

In an effort to put X-ray exposure in perspective with background exposure, Table 8 shows the relative exposure in days of the most common dental X-rays. A full volume CBCT X-ray is equal to approximately nine days of background exposure. When one considers the amount of background exposure each person receives in a year, a single CBCT X-ray is comparable to around two percent of that. The entire full mouth series of dental X-rays, using digital film and round collimation, is equal to only approximately 21 days, or just under six percent of that.


Fig. 1

It is of value to state that everyday activities also produce background radiation. For example, airline travel adds to one's radiation exposure and can easily be compared to ones CBCT exposure (see Tables 9 and 10). Generally the public is unaware or unconcerned about background exposures of this nature.

However, the aviation industry has always been very concerned about the exposure of their pilots to radiation while flying the many hours each year. A study was done to evaluate the incidence of cancer among Nordic airline pilots over five decades involving 10,032 pilots in a 17-year follow-up period. The conclusion: "This study does not indicate a marked increase in cancer risk attributable to cosmic radiation."

Of course, when it comes to X-ray exposure, most people simply want to know the risk they have of contracting cancer

Table 7

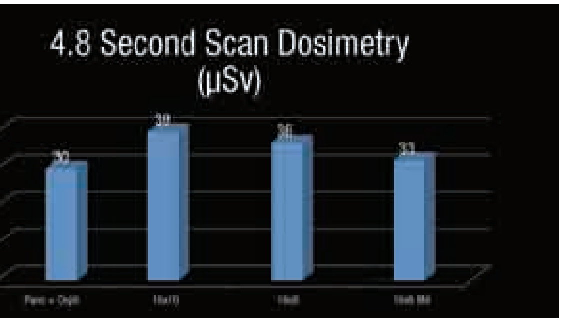

Table 7: Internal testing by Imaging Sciences International performed in 2011 using protocol as described in Ludlow and Ivanovic. Data provided by Ed Marandola

Table 8: Relative exposure in days of most common dental x-rays

Digital BW or Digital Lateral Cephalometric device = 5.6 µSv	Days of per capita background, ICRP 2007 = **<1**
Planmeca ProMax Digital panoramic device = 24.3 µSv	Days of per capita background, ICRP 2007 = **3**
Next Generation i-CAT Full Volume CBCT (8.9s) = 74.0 µSv	Days of per capita background, ICRP 2007 = **9**
Digital FMX or F-speed film with round collimation = 170.7 µSv	Days of per capita background, ICRP 2007 = **21**

Table 9

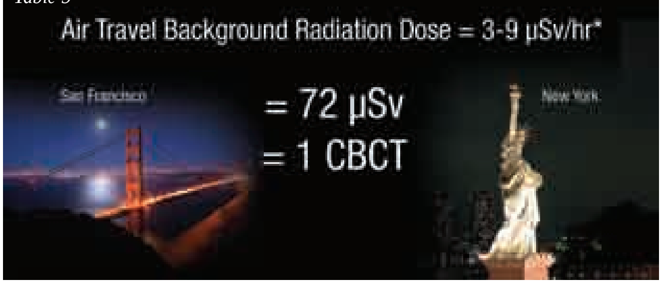

Table 10

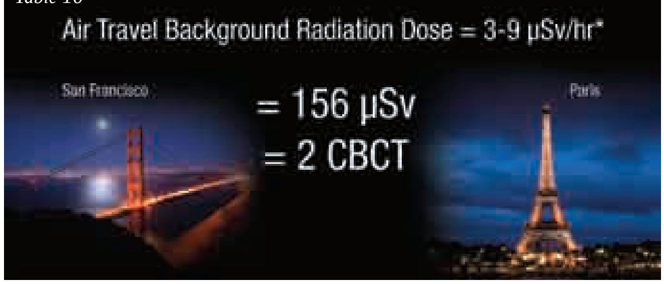

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Table 11

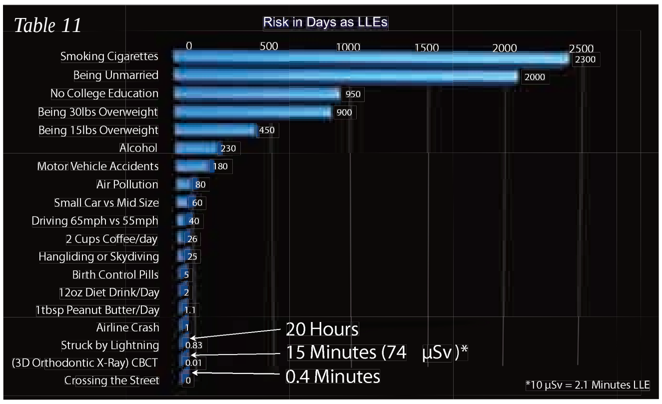
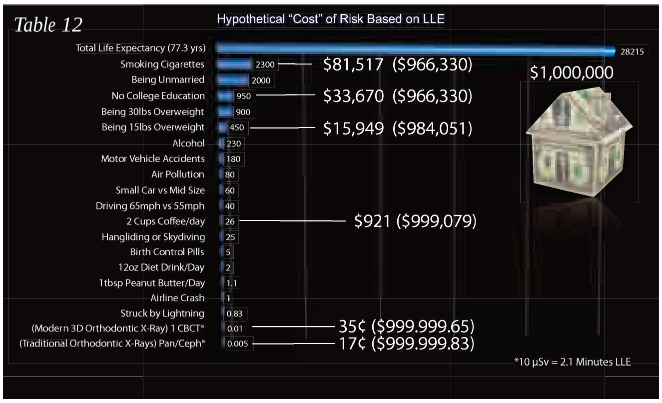


Table 12

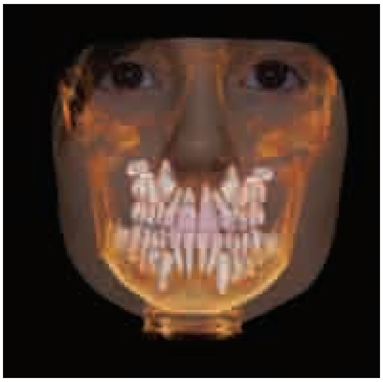


from the procedure. This is where nuclear scientists have contributed a significant amount of information. Using their statistics, and a calculation known as Loss of Life Expectancy (LLE), we can put in perspective where ionizing radiation falls in comparison with other life risks.

Table 11 shows the relative risks of some common everyday experiences. For example, we know that there are risks associated with drinking alcohol and being overweight, but many of us choose to accept these risks based on perceived benefits from these practices. By contrast, it is well known that the benefits of dental X-rays, in particular CBCT, far outweigh the extremely small risk of the procedure.

To put this in even more perspective, Table 12 shows these risks relative to our overall lifespan. If we consider our total life to be valued at approximately $1,000,000, the risk of a CBCT scan is the equivalent of approximately 35 cents. Notice that a more common risk, such as drinking coffee, is equal to $921. What is interesting to note in this figure, is that the difference between a CBCT X-ray and a traditional pan/ceph combination is only 18 cents. This is a miniscule increase when compared to other more common risks. When the risk increase is miniscule, and the diagnostic benefit very large, it seems that it would be easy to explain why a movement to CBCT should not be an argument about increased X-ray exposure risk.

To bring the point home, we should consider the risks and benefits of air travel. Most of us would not hesitate to get on an airplane with our entire family. This would include our young children and our infants. However, the risks of ionizing radiation with flying are well known facts. These risks have been studied in detail to protect airline workers such as pilots and flight attendants. Table 9 shows the ionizing radiation exposure for round-trip flight from San Francisco to New York. The exposure for this trip is approximately 72µSv, equal to one CBCT scan. When put in perspective with the benefits of flying, most of us neglect the associated risk. Why we don't disregard the risks of dental X-rays, it simply comes down to how these issues are presented to the public.



Again, when we discuss the move in orthodontic imaging from a traditional pan/ceph to CBCT, it should not be an argument about increased exposure risk. That would be like arguing that one should only fly one-way to New York because the return trip would be too much radiation exposure.

Observing basic human nature shows us that people tend to accept risk that they impose on themselves, but are reluctant to accept the risks that are imposed on them by others. Therefore, when a doctor says, "You need an X-ray," most people question this if they do not see any immediate benefit. As a profession, it is our job to educate the public regarding the risks of X-rays, but more importantly, to clearly explain the benefits of CBCT radiation exposure. The benefits of CBCT X-rays far outweigh the increased risks. This is well described in previous *Orthotown Magazine* articles and will be a topic of interest in issues to follow this one. Also, search: "CBCT" on Orthotown.com for more information and discussion.

When it comes to 3D X-rays, we must explain that the increased exposure is miniscule, but the diagnostic benefits are extraordinary. We must use the scientific research data, some of which is presented here, to help separate emotional responses from rational ones. We have the facts at our fingertips. As a profession, we must present these facts in an easy-to-understand way that puts dental X-ray risks in perspective with those risks of everyday living, which are generally accepted by the public.

Perhaps an example that most Moms can identify with is the new procedure being utilized for mammograms. At a local imaging center in Phoenix, Arizona, there is a sign welcoming patients announcing "3D tomosynthesis" being used for routine mammograms. This is a CBCT scan that is done *in addition* to the conventional 2D X-ray. The total radiation for this "routine" procedure is 283.3 mRads (per laboratory documents).

285 mRads is equal to 0.235 Rads, which is equal to .00235 Sieverts or 2,850 micro Sieverts. Given the current full volume i-Cat exposure of ~74 micro Sieverts, you could take more than 38 full-volume CBCT scans before equaling a single "tomosynthesis" mammogram. Not only is this something that we can use when equating orthodontic diagnosis to female medical diagnosis but we particularly like the term "tomosynthesis," although it is used exclusively for mammograms (Digital tomosynthesis combines digital image capture and processing with simple tube/detector motion as used in conventional radiographic tomography. Although there are similarities to CT, it is a separate technique).

Consider a mother being informed that her child needs a CBCT scan similar to tomosynthesis, just like they use for mammograms at the imaging centers with only 1/38th the radiation. Would this be more common terminology that would make sense to her?

If you had a diagnostic tool that was simple to use, reduced time in treatment and the risk of the root resorption, caries and decalcification and provided far more accurate information – would you use it? If the diagnostic tool could be used with 1/38th the radiation exposure of a routine medical procedure – why wouldn't you use it?

"If a picture is worth 1,000 words, then a cone beam scan is worth 1,000,000 pictures*** ■

Defining CBCT

Dosimetry: The calculation of the absorbed dose of radiation in matter and tissue resulting from the exposure to indirect or direct ionizing radiation.

Sievert: International System of Units (SI) derived unit of dose equivalent radiation. A milliSievert (mSv) equals 1/1,000 Sv. A microSievert (µSv) equals 1/1,000,000 of a Sv (most often used in dentistry).

Gray: The SI unit of absorbed radiation dose of ionizing radiation.

Link to the International Commission on Radiological Protection (ICRP) occupational dose limits: www.remm.nlm.gov/ICRP_guidelines.htm

*** Internal testing by Imaging Sciences International performed in 2011 using protocol as described in Ludlow and Ivanovic, 0000E, 2008 (Permission provided by Ed Marandola)*

****Editors note: At one-degree increments a 3D CBCT is 360 x 360 x 360 = 46,656,000 pictures.*

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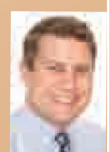
Author Bios

Dr. Sean Carlson is a board certified orthodontist who received his dental degree from Harvard University in 1994, where he was awarded the American Association of Orthodontists Award. He received his orthodontic specialty training and his Master of Science degree in Oral Biology from the University of California at San Francisco. He is currently an associate professor of Orthodontics at the University of the Pacific School of Dentistry and maintains a private practice in Mill Valley, California. Dr. Carlson is a senior investigator in the Craniofacial Research and Instrumentation Laboratory at the University of the Pacific. There he has served as principle investigator for a series of research grants and has published numerous papers and abstracts on a variety of clinical and theoretical subjects. His primary focus is on using computer technology to improve the way we study, teach and practice orthodontics.

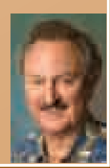
Dr. John Graham lectures worldwide to both doctors and orthodontic staff on the most advanced orthodontic treatment philosophies available. He received his Bachelor of Science degree from Brigham Young University, a dental degree from Baylor College of Dentistry in Dallas, Texas and then a medical degree from the University of Texas Southwestern Medical School. After medical school, Dr. Graham completed an internship in general surgery at Parkland Memorial Hospital followed by training in oral and maxillofacial surgery. Following his surgical training, Dr. Graham received his certificate in orthodontics from the University of Rochester/Eastman Dental Center in Rochester, New York. He was a featured speaker at the 4th international Congress on 3D Dental Imaging in La Jolla, California.

Dr. William "Bill" Harrell graduated from the University of Alabama in Birmingham (UAB) School of Dentistry with a DMD degree in 1975, and received his certification in orthodontics from the University of Pennsylvania in 1977. Dr. Harrell became a diplomate of the American Board of Orthodontists in 1989 and is a member of the College of Diplomates of the American Board of Orthodontists. Dr. Harrell has served as president (1987-1988) and vice president (1986-1987) of the 9th District Dental Society of Alabama and during that time served on the Alabama Dental Association's Board of Trustees and House of Delegates. Dr. Harrell has served as the president (1990-1991) and vice president (1989- 1990) of the Alabama Association of Orthodontists and served as a director to the Southern Association of Orthodontists from 1995-1997. Dr. Harrell also teaches at the University of Alabama Birmingham and the University of Pennsylvania. Dr. Harrell served as the American Association of Orthodontist's (AAO) Representative to the American Dental Association (ADA) Standards Committee on Dental Informatics (SCDI) from 2002-2009. Dr. Harrell has had an interest in 3D imaging since the early 1980s and has numerous scientific articles, text book chapters and lectures both nationally and internationally on 3D Imaging, TMJ disorders and sleep apnea as it relates to maxillofacial growth.

Dr. Ed Lin is an internationally recognized speaker and full-time practicing orthodontist and partner at both Orthodontic Specialists of Green Bay (OSGB), in Green Bay, Wisconsin, and also Apple Creek Orthodontics (ACO) in Appleton, Wisconsin. Dr. Lin received both his dental and orthodontic degrees from Northwestern University Dental School ('95, DDS; '99, MS).



Dr. Aaron Molen received his DDS from Loma Linda University and his orthodontic training at UCLA. Dr. Molen has given multiple lectures on the topic of CBCT at meetings for the AAO, PCSO, Angle and RMSO. In addition, he is the chair of the CBCT subcommittee on the AAO's committee on orthodontic information technology. Dr. Molen serves as a peer reviewer on the subject of technology for the AJO-DO and the Angle Orthodontist. Dr. Molen has published several papers on the topic of CBCT in the AJO-DO, seminars in orthodontics and practical reviews in orthodontics. He maintains a Web site on the subject of CBCT, www.3DOrthodontist.com and is on faculty at UCLA where he lectures on CBCT. Dr. Molen is in private practice in the Seattle area with his father and brother.



Dr. Wm. Randol Womack is a board certified orthodontist, and practices and is a partner at Affiliated Orthodontics in Peoria and Glendale, Arizona. Dr. Womack is also the editorial director of *Orthotown Magazine.*