CDA

Implant Placement
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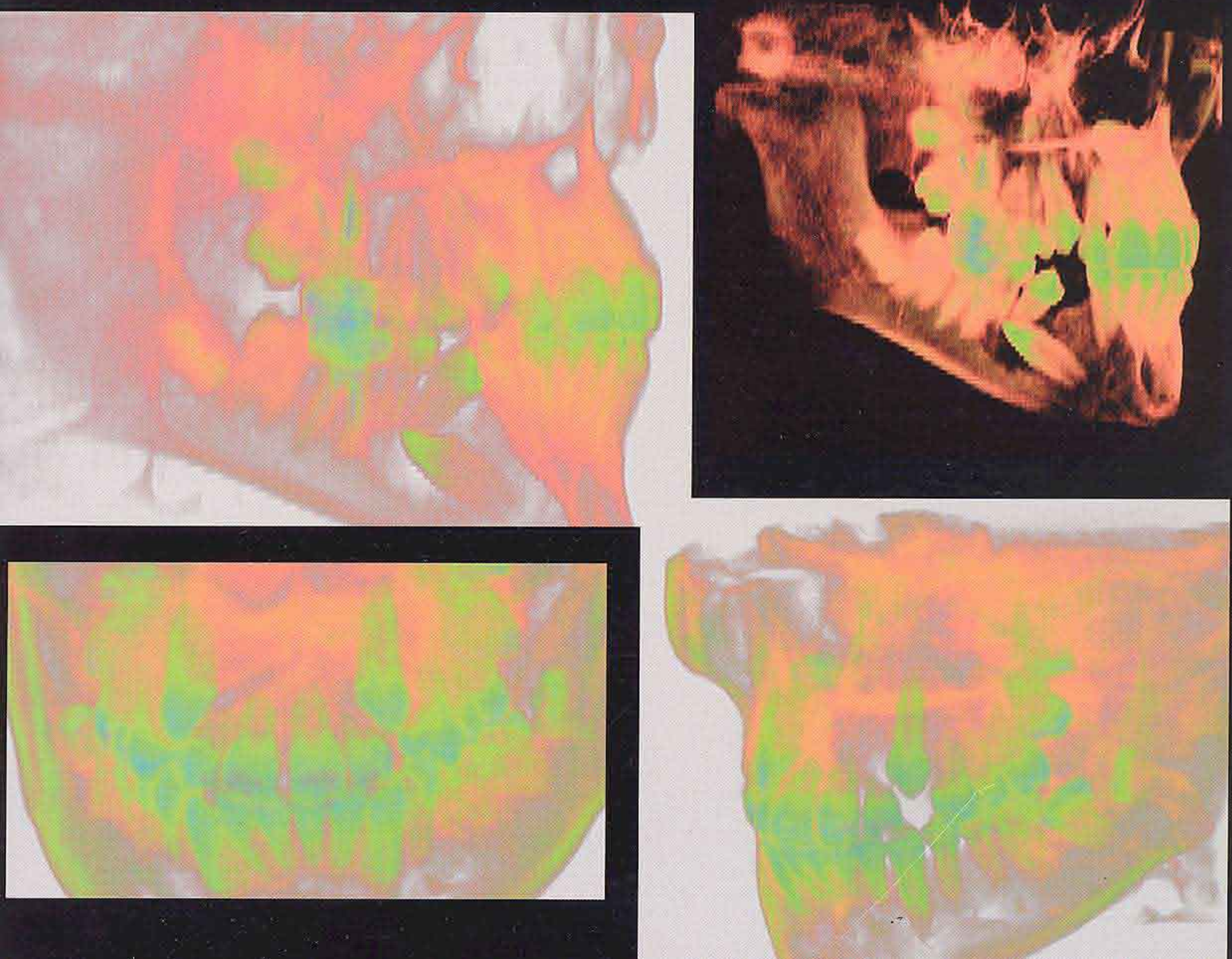
Robert A. Danforth, DDS



OF THE CALIFORNIA DENTAL ASSOCIATION
Journal

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DEPARTMENTS

FEATURES

Steven A. Gold, DDS

When Nobody's Looking

I've been told the story that when my older brother was just a toddler, he was admonished never to step foot off the curb unless he was holding an adult's hand. As long as an adult was nearby, he was obedient. But, when nobody was looking (or so he thought), he went directly to the curb and gingerly placed one foot onto the asphalt even though he knew it was the wrong thing to do. This behavior came to a swift end when our mother properly punished him. In those days, it was an open hand on a bare bottom. By the time my brother and I had flown the nest, I am sure my punishments for similar offenses far outnumbered his. It took me the better part of my first 20 years to learn that it's what you do when nobody's looking that counts.

These days, I have a new perspective on the subject of behavior. I am in a profession that holds ethical conduct in high regard. We have ethics classes, codes of ethics, even professional organizations dedicated to advancing ethics in our profession. Why is it, then, that so many members of the profession are up in arms over the current state of ethical behavior in dentistry? It seems as though every dentist I talk to has witnessed or experienced some form of unethical conduct amongst his or her peers.

During my time in dental school and as a practicing dentist, I have witnessed dental students cheating by various means: copies of tests had been removed from instructor's offices, answers have been shared during exams, pre-clinical projects have been done by upper classmen or outside dental laboratories and passed off as the student's own. I have seen students who were caught cheating receive light reprimands, a failing grade or class demotion, rather than expulsion. I have witnessed employer dentists callously take advantage of their associates, employees, third-party payers, and patients in the name of increasing their bottom line. I have both seen and heard stories of employees, dentists and non-dentists alike, stealing not only money but also confidential patient information with the sole intent of advancing their own careers, status or income. I have witnessed, first hand, the theft of dental association handpieces and continuing education forms at our own CDA Scientific Sessions.

In spite of the fact that these offenders are a minority in a profession filled with caring, selfless and giving individuals, they nevertheless leave a bad mark on dentistry. Just as individuals are often judged by their last worst deed, so too are professions such as ours often judged by their members' worst actions. We have become aware of the fact that as dentistry's leaders seek to protect and advance the profession, our public image becomes of paramount importance. We can ill afford to have the collective reputation of dentists everywhere besmirched by the unprofessional behavior of a few.

Like so many of you, I take such intentional deviations from moral and professional conduct as a personal affront, and with this in mind, I offer a three-pronged attack to combat this decline in ethics so many of us have witnessed.

■ **Education.** Educating dental professionals about ethics must occur at all levels of the profession. It, of course, begins at our dental schools. In fact, it should begin before dental school. Acceptance into dental school constitutes an individual's entrance into the dental profession and thus acceptance should be contingent upon both an understanding of ethics and an oath to up-

Just as individuals are often judged by their last worst deed, so too are professions such as ours often judged by their members' worst actions.

hold the ethical standards that have been established for the profession. It is incumbent upon dental schools to continue teaching ethics throughout the entire curriculum. It is further incumbent upon our profession to offer, even demand, continued learning experience on the subject of ethical and professional conduct and decision making throughout our careers.

■ **Discipline.** When violations of ethics occur, the body responsible for the individual must take appropriate, yet decisive disciplinary action. Dental school leadership must be unwavering in the fair and uniform application of their rules of ethical conduct. Furthermore, they must have the courage to put their foot down and expel repeat or incorrigible violators, even at the risk of loss of tuition revenues or retaliatory legal action by the offenders. Our state licensing boards must similarly be vigilant over those who breach their moral obligations as dentists. Where gaps exist between law and ethics, we should seek to close them. Until we establish a zero-tolerance policy for ethical violations, we will allow those seeking to compromise ethical behavior in favor of personal gain to flourish.

■ **Commitment.** Relegating responsibility for an individual's behavior to a school, professional organization or a state's dental board is merely shifting that responsibility from where it truly belongs: with the individual. Therefore, a strong commitment to ethical conduct from all dental professionals must exist in order to preserve the high level of public trust and respect the profession wholly deserves. Demanding that individuals adhere to our CDA and ADA codes of ethics is a good start, however, these codes do not cover all areas where lapses in ethical behavior exist. I have found a more inclusive moral compass to be the Six Pillars of Character. These six pillars are trustworthiness, respect, responsibility, fairness, caring, and citizenship. Clearly, it is possible to devote much time and space to the discussion of each. Suffice to say that these principles can provide a sound basis for ethical decision making in dentistry and all aspects of life.

Decision making is easy when we have someone, such as loving parents, telling us what is right and what is wrong. It becomes much more difficult as we gain the freedom and independence we seek in our personal and professional lives as adults. Nevertheless, it is these decisions we make, when nobody's looking, that have a profound influence on us as individuals and on the profession of dentistry as a whole. CDA

Arthur A. Dugoni, DDS

Protection of the Public

In September, we expressed our views on the current California licensure examination relative to its primary purpose of protecting the public. Those comments prompted an eloquent supportive response from the distinguished past President of the American and California Dental Associations, and longtime Dean of the University of the Pacific School of Dentistry, Arthur Dugoni.

We believe it is must reading for all California dentists. — The Editor

In many articles that I have authored on the subject, I have expressed a continuing concern for the validity of initial licensure on the premise that it **protects the public**. There is no validity to the outcomes as demonstrated quite clearly by Dr. David Chambers and other psychometricians. The issue that I have put on the table my entire career is that the domain of the dental boards of licensure should concentrate on 1) continued competency of the practicing profession, and 2) the enforcement needed to monitor the profession with respect to wellness, substance abuse, and inappropriate professional conduct and competency.

Initial licensure of recent graduates does not **protect the public**. There is no validity to this that can be demonstrated at all. Your editorial states that 98 percent of the recent graduates of California Dental Schools passed the clinical examination within one year. Those who previously failed do this in the majority of cases without ever having taken any enforcement or enhancing programs to prepare them to pass the board examinations. The "one-shot" examination does not ensure protection of the public, and to my mind that is the only reason why dental boards exist — **protection of the public**.

The dental schools of this country are charged with educating a competent practitioner and this is evaluated regularly by the Commission on Dental Accreditation and by students' passage of Part I and Part II of the National Boards. I believe that this state and this nation would be better served by the elimination of initial licensure examinations and granting licensure to graduates who have passed Part I and Part II of the National Boards, and have been certified as competent by the deans and faculty of their respective dental schools.

We have spent at least (during my professional career) the last five decades tweaking around the margins of the licensing examination. Whether it is substituting a perio examination for a gold foil, or a root canal procedure for a reverse ¾ crown, it still begs the question — do one-shot initial licensure examinations **protect the public?**

The current system is archaic and indefensible. It increases the cost and indebtedness of the student; it delays their entry into private practice; and ultimately it delays the opportunity for practitioners to enter practice and render care to a vastly underserved group of patients.

If it could be demonstrated that there is validity in the "one-shot" examination as meeting the standard of **protection of**

Do one-shot initial licensure examinations protect the public?

the public — I would be first in line to support it. I have worked hard my entire professional career to support licensure, even though I did not believe that it met the purpose of the Dental Board of California, which must be protection of the public. The Board spends large amounts of California dollars and candidates' dollars on initial licensure examinations, when dollars and personnel time could be better spent on continued competency of the practitioner and stronger avenues of enforcement and identification of individuals who are practicing at an inappropriate standard of care, or are guilty of various infractions of the state dental practice act.

The concern and outright anger by the practicing community for initial licensure, especially by students, faculty, deans of dental schools, and even leaders in organized dentistry have never been more evident. The ferment continues with resolutions submitted ad nauseam at meetings of specialty groups, student leader organizations, and the House of Delegates of the American Dental Association. Never a year goes by that there is not a parade of resolutions to do something about the licensing exams. Recent actions to grant licensure to individuals who have completed a one-year postdoctoral general dentistry residency or specialty program of one year by New York, Minnesota, and Washington are examples of only putting "fingers in the dike" and not a solution to the problem.

Why is the completion of a postgraduate program (in which there are no examinations or competency evaluations performed on the residents) an indicator that these individuals will practice dentistry the rest of their lives at the appropriate level to protect the public? It is just another symptom that something is wrong with initial licensure. What about licensure by credential? Important as it is, is this another "finger in the dike"? The platform with respect to licensure by credential continues to change from five years of practice to one year of practice to zero years of practice to be eligible for licensure by credential and therefore allowing freedom of movement for the professional and access to care for patients. I am in complete support of licensure by credential as a means to facilitate freedom of movement by our profession.

> The majority of individuals practicing throughout the United States have taken one licensing examination to determine competence and that was at graduation or when they moved into another licensing jurisdiction.

If the state boards and the regional boards of this nation really believe that initial licensure **protects the public for a lifetime of practice**, I fail to understand it. Let them prove it! If the dental boards of this nation believe that initial licensure is a guarantor that the deans and the professors of dental schools are doing their job producing competent dentists, then that is another issue. Is there no validity to the evaluation and accreditation of dental schools by the Commission on Dental Accreditation? Is there no validity to the successful completion of Part I and Part II of the National Boards? Are deans and faculty dishonest and fraudulent when they certify competency with a doctorate in dentistry at graduation?

The time has come for the profession to do it before the legislators of this nation decide they are fed up with initial licensure as the avenue to protect the public. Washington, Minnesota and New York are examples of how licensure can be changed by the legislators of this country in the "blink of an eye."

Initial licensure examinations do not **protect the public**. The majority of individuals practicing throughout the United States have taken one licensing examination to determine competence and that was at graduation or when they moved into another licensing jurisdiction. They continue to practice for a lifetime without ever again demonstrating competence. Is this protection of the public? Could not the limited resources (dollars and personnel) of each licensing jurisdiction be better spent on appropriate avenues of continued competency, evaluation, and enhanced enforcement activities? My concerns for initial licensure reform do not in any way indict the dedication and efforts of state and regional board examiners. They work industriously to carry out the process. My opposition is to initial licensure as a means to **protect the public**.

Members of the state and regional boards will continue to be welcomed by the educational community to enter into the evaluation of the educational programs and competency of graduates. Few dental boards or regional jurisdictions participate in the Commission on Dental Accreditation site visits to dental schools. In the examples that I am familiar with (in over 50 years as a faculty member and 25 years as a dean), whenever the dental board presidents or leaders of the dental boards have participated in accreditation site visits, they have come away amazed at the quality of the educational program and the programs that have been instituted at schools of dentistry to determine competency of the students as they progress through the educational program from novice to beginner to competent. The final two stages to becoming a professional proficient and expert are not realized until later in a professional's career.

The Task Force to evaluate existing and alternatives in California clinical licensure examinations and report to the 2003 CDA House of Delegates should lead to exciting discussions and hopefully, meaningful resolutions to take on the concept — do initial licensure "one-shot" examinations really protect the public? CDA

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PS Form 3526, October 1999 (Reverse)

Illustration: Polly Powell

Source of Black Death Revisited

Centuries old, Black Death is not a thing of the past. Many residents of the tropics remain susceptible to and can be infected by Yersinia pestis. And there is some fear it could be used as a biological weapon.

As such, there is renewed interest and much debate over the origin of the plague that not only decimated half of the European population in 1348, but has lingered for nearly 700 years.

"We cannot rule out Yersinia as the cause of the Black Death," said Alan

Knowledge is Key to Making Healthful Choices

An estimated $58 billion added health care costs a year can be attributed to poor health literacy. The more informed an individual is, the better the chances are of decreasing obesity, being overweight and other chronic diseases.

"The health of our country depends on our understanding of basic health information in order to lead a healthy life," said Tommy G. Thompson, Health and Human Services secretary. "If children and adults think about the consequences of inactivity and a poor diet each day, they are beginning to take the necessary steps to lead a healthy lifestyle."

For example, patients with Type 2 diabetes are associated with poor glycemic control and elevated rates of complications than those who are better informed about their condition. Although the person may have an understanding of their health problem, they may have difficulty with some concepts and vocabulary related to diabetes.

Wise choices about meals and moderate physical activity made now could have positive effects 10, 15 or 20 years later, resulting in strides made in improved productivity and the health care system.

Cooper, head of the Ancient Biomolecules Centre at Oxford University, UK. "But right now there is no molecular evidence for it." Cooper's team conducted the latest research.

But researchers, headed by Susan Scott and her colleague Chris Duncan of the University of Liverpool, UK, concluded Yersinia was not the source of the plague but believe a virus like Ebola, one that causes heavy bleeding (*New Scientist* print edition, 24 November 2001).

Initial investigations pointed fingers at bubonic plague bacterium Yersinia pestis, which is transmitted courtesy of fleas and rats. However, recent analysis did not find Yersinia in the victims' remains. This is contrary to a French research team's assertion that they had found Yersinia in the remains.

There also was some speculation of the accuracy of the French team's findings. Three years ago, Didier Raoult and his colleagues at the University of the Mediterranean in Marseille, France, used the teeth of three 14th century bodies in their DNA testing. Raoult's team said the DNA sequences included some unique to Yersinia.

Scott and others questioned whether the remains used in Raoult's tests were from those killed by the Black Death. Raoult rejected their claims calling it "unsubstantiated speculation."

In their study, Oxford University's Cooper and his colleagues looked at more than 100 teeth from 66 skeletons found in five mass burial mounds for those who died of Black Death in 1349. Other graves in England, Denmark, and France also were examined. The team used primers, DNA fragments that act as probes in the PCR test to amplify certain sequences unique to Yersinia.

None of the 122 teeth analyzed had identifiable Yersinia DNA, Cooper said. "And we used the same primers the French used ... We detected a lot of different bacteria, but none of the sequences were from Yersinia."

> "If I can get some soft tissue from the plague, I'll look again."
>
> ALAN COOPER

Raoult maintains his team avoided bacterial contamination in splitting and excavating the teeth. However, in a control test conducted by Cooper's team using modern DNA of Yersinia, there was a positive result from one tooth but it had been contaminated by modern DNA.

Despite the setback, Cooper's team found human mitochondrial DNA in the teeth, further proving DNA could survive. Not finding the Yersinia DNA doesn't confirm the victims died of Black Death, the bacterium just may not have permeated to their teeth.

"If I can get some soft tissue from the plague, I'll look again," Cooper said.

In Raoult's study, the 14th century skeletons his teams used came from Montpellier. Almost all of his team's samples tested positive, a questionable result given the warmer climate and the DNA survival rate, Cooper said. Coupled with the imprecise primer test, Cooper is not convinced the French team identified the Yersinia dating back 700 years.

However in colder climes, such as Finland, victims buried in permafrost could make for conclusive results.

No Rise in Dental Fear Despite Elevated Anxiety Level

Patients are finding themselves more comfortable in the dental chair these days thanks to advances in techniques and technology.

Despite an increase in general anxiety in the U.S., studies reveal dental anxiety has not risen according to an August 2003 article in the *Journal of the American Dental Association*.

Previous studies showed direct links between an increase in general anxiety level and an increase in dental fear.

"The fact that dental anxiety is not rising when dentists are treating increasingly anxious patients is a tribute to advances made in dental technology and patient management skills," wrote investigators from the University of Kentucky's College of Medicine.

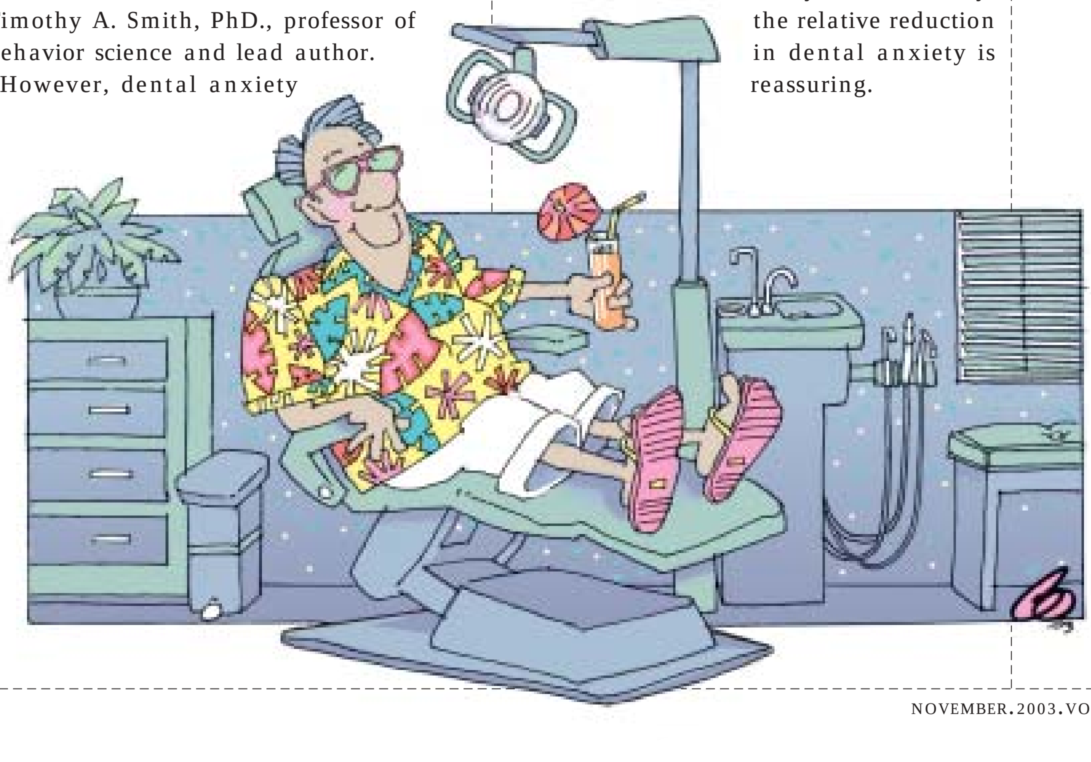
"Owing to this strong direct relationship between general anxiety and dental fear, we might expect a rise in the latter to follow an increase in the former," said Timothy A. Smith, PhD., professor of behavior science and lead author. "However, dental anxiety does not seem to follow the trend of increasing general anxiety in the United States."

In the JADA report, authors pored over 200-plus articles, comparing 19 studies involving more than 10,000 adults to assess any mean anxiety scores for general adult and college student samples. Four measures of dental anxiety were used.

The findings? Dentistry has changed over the last 30 years. The adoption of lasers, bonding procedures and other less technically threatening methods to treat patients has had a profound effect.

These efforts appear to have had an impact on the problem of dental fear in our society and may be why 63 percent of adults surveyed in 1997 felt that less pain was involved during a dental visit as an adult than it was as a child, the authors said.

The authors also concluded that in comparison with the rising tide of general anxiety in the country, the relative reduction in dental anxiety is reassuring.



Sixty-three percent of adults surveyed in 1997 felt that less pain was involved during a dental visit as an adult than it was as a child.

Gene Therapy Will Help Unlock Secrets of Saliva

Gene therapy may hold the key in treating patients with salivary dysfunction.

Chih-Ko Yeh, PhD, BDS, associate professor of dental diagnostic science at the University of Texas Health Science Center in San Antonio, and fellow researchers are hoping to treat the problem by regenerating the salivary gland.

"Gene therapy would be an ideal way to treat this disorder," Yeh said in an article in May 2003 issue of *The Mission*.

"We could inject the gene therapy directly into the glands themselves. That's our dream. We're working on it."

Saliva aids in digesting food, but its central role is protecting the mouth's tissue against decay and disease. On the average, a person produces more than two cups of saliva every day. Those who produce less and patients with salivary dysfunction are prone to serious risks to their overall health.

Those with less than average saliva rates experience complications in swallowing, chewing and talking. The high concentration of calcium in the saliva prevents teeth from dissolving. Coating the mouth to maintain hydration, saliva's anti-microbial proteins also guard against disease. The proteins, according to the article, protect the body from viruses and bacteria attempting to enter via the mouth.

Yeh and his colleagues hope to learn how saliva and salivary glands are affected by age, HIV infection and Sjogren's syndrome. Despite the widely held view that saliva is not affected as a person ages, researchers say it is a factor.

"We're finding a link between salivary dysfunction and major diseases like diabetes, hypertension and HIV," said Yeh. "And we also see a correlation between salivary dysfunction and certain drugs."

Senate Confirms Appointment of Dentist as Indian Health Service Director

Public Health Service dentist and rear admiral Dr. Charles W. Grim recently was confirmed by the U.S. Senate as director of the Indian Health Service (IHS).

"Since his appointment as interim director last August (2002), Dr. Grim has demonstrated his ability as a compassionate leader, effective manager, and worthy advocate for Indian Health programs," said HHS secretary Tommy G. Thompson.

A 1983 graduate of the University of Oklahoma College of Dentistry, Dr. Grim started his career as a Public Health Service commissioned officer. In his four-year post as IHS director, he will administer the nationwide, multi-billion dollar healthcare system providing curative, preventative and community general and oral healthcare services to an estimated 1.6 million American Indians and Native Alaskans. Dr. Grim, who will be promoted to the rank of two-star admiral, is a member of the Cherokee Nation of Oklahoma.

"I will strive to ensure that the IHS continues to be an organization that is very sensitive to the cultural beliefs and traditions in the communities we serve," said Dr. Grim. "The greater involvement of Indian tribes and Indian people in decisions affecting their health has helped produce significant health improvement in their communities."

Give Kids a Smile Registration Streamlined

Registering on the web for the Feb. 6, 2004, Give Kids a Smile just got a whole lot easier. Simply go to www.cda.org, follow the link to the forms, fill them out and submit them online.

Additionally, CDA has a separate form requesting the name of the participating society, the date of the event, time, location, a brief description of the event, and the ages of children treated. Participants should submit this information to Molly Woodward at CDA via fax (916) 442-2943, or send it to her attention at 1201 K Street Mall, P.O. Box 13749, Sacramento 95853. The deadline to submit this form is Dec. 3. Please note that submitting this participation form to CDA does not automatically register participants for the Give Kids a Smile program.

If participants need assistance with publicity prior to the event, they should submit a Request for Local Press Release form via fax or mail to Woodward at CDA by Dec. 8.

Following the event, participants should update their information to assist CDA in evaluating the campaign and obtaining data such as the total number of children treated, volunteers donating their time and skill, and the quantity of programs held throughout the state.

Last year, 5,000 Give Kids a Smile care sites across the country treated an estimated one million low-income children. The free services, which also included education, screening and treatment, were valued at $100 million.

The Missing Link in the Child Identification Program

Of the estimated 840,300 people reported missing in 2001 in the U.S., approximately 85 to 90 percent of them were underage. With teens and children, now more than ever, at a higher risk of being abducted, it is important to have identification process in place.

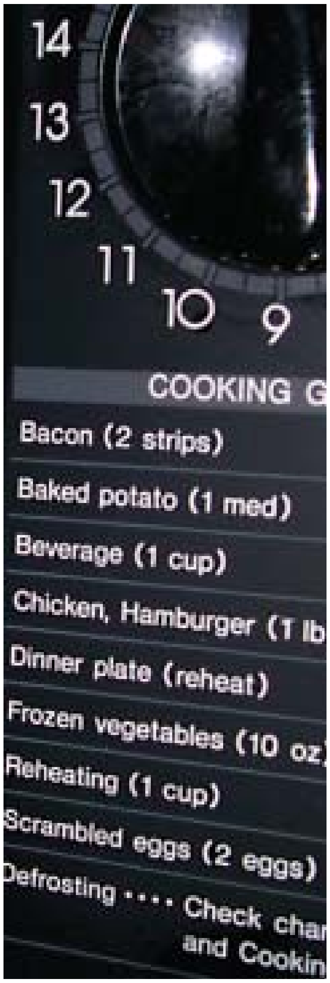
Enter Toothprints® a bite impression and link to CHIP (Child Identification Program), a tool many states have used over the last two decades.

CHIP originally utilized a videotaped interview and fingerprinting as part of its identification program. Five years ago, Dr. David B. Harte, a dentist and current CHIP director, implemented the bite impression component to make CHIP the most complete identification program in the U.S, wrote Laura J. Najjar, CDA, BA, MEd, in the March/April 2003 the *Dental Assistant*.

Like fingerprints, toothprints are distinctive, and because teeth can endure temperatures up to 5000 degrees, it is far stronger. Additionally, saliva provides a DNA sample and can be a substantial scent tracer for police dogs.

Najjar suggests children leave a spit trail if lost in the mountains or forest. This "trail" can assist search and rescue canine teams.

The use of dental sealants, dental education and fluoridated water, juveniles' teeth often are restorative-free, thus making positive identification a challenge through dental charts. Najjar said the toothprint is extremely conclusive. It can distinguish the imprint of a dental sealant which children commonly have.



Zapping Your Water Could Be Risky

Heating water in a microwave could potentially blow up in your face. That's because microwaves heat things quicker and more evenly than a stove. What's more, using a newer cup adds to the hazard, said physicist Steve Snyder, PhD, of the Franklin Institute Science Museum in Philadelphia.

"If the cup is new, smooth and clean, there's a chance the water in it can be a good bit past the boiling point, and there might be no bubbles at all to warn you about the temperature," Snyder said in the spring 2003 *Living Healthy*, a newsletter of the Blue Cross Blue Shield and Blue Care Network Michigan.

The fewer flaws in the container, the less likely there will be bubbles indicating water is at the boiling point. On the other hand, an older cup probably is more uneven and worn. Such imperfections allow bubbles to form.

"We don't realize how quickly water is becoming so hot when it happens behind the closed door of the microwave," Snyder said.

Glass, Snyder cautioned, presents more of a potential for catastrophe because of its smoothness. Taking the cup from the microwave tends to jar the superheated water. Numerous bubbles can immediately form, causing the water to explode.

Use a kettle on the stove to boil water, recommended Snyder. "But if you use the microwave, check the water frequently and absolutely never look closely at the cup to determine how hot your water is."

Upcoming Meetings

2003

Nov. 2-7	U.S. Dental Tennis Association Annual Meeting, Palm Desert, Calif., (800) 445-2524.
Nov. 8	Association of Managed Care Dentists, LAX Marriott, Calif., (310) 453-3439, www.amcd.org.
Nov. 8-9	International Conference on Evidence-Based Dentistry, Chicago, j.ryley@elsevier.com
Nov. 16-22	Annual Meeting of the United States Dental Golf Association, Scottsdale, Ariz., (631) 361-7127, usdga@optonline.net.
Dec. 5-7	California Academy of General Dentistry Annual Meeting, San Diego, (877) 408-0738, www.cagd.org.

2004

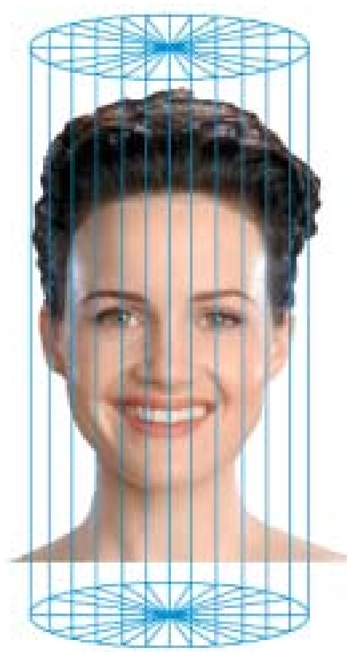
March 3-6	Academy of Laser Dentistry 11th Annual Conference, Palm Springs, Calif., (954) 346-3776, www.laserdentistry.org.
April 15-18	CDA Spring Scientific Session, Anaheim, (866) CDA-MEMBER (232-6362).
Sept. 8-11	International Federation of Endodontic Associations Sixth Endodontic World Congress, Brisbane, Queensland, Australia, www.ifea2004.im.com.au.
Sept. 10-12	CDA Fall Scientific Session, San Francisco, (866) CDA-MEMBER (232-6362).
Sept. 30-Oct. 3	ADA Annual Session, Orlando, Fla., (312) 440-2500.

To have an event included on this list of nonprofit association meetings, please send the information to Upcoming Meetings, *CDA Journal,* P.O. Box 13749, Sacramento, CA 95853 or fax the information to (916) 443-2943.

Cone Beam Volume Tomography: A New Digital Imaging Option for Dentistry

Robert A. Danforth, DDS

Dentistry continues to "go digital." Use of digital radiography has increased in private practice, particularly with endodontists. Computed Tomography (CT) is routinely performed for dental implant imaging, and many dental schools are moving toward a paperless and filmless environment. As this trend continues, a question is "What are we trying to achieve?" Is it just a fast way to get an image? A method to reduce patient record storage? Save the environment from processing chemicals? Reduce remakes by digitally adjusting contrast and brightness? Or, is there a greater possibility?



The future is not on the distant horizon but rather is developing in the present.

My view is that the greater imaging goal for dentistry is development of the 3-D patient model. An anatomically accurate "virtual patient" upon which diagnosis, simulation and treatment planning could occur. Use of medical digital imaging has progressively increased in dentistry. CT, MRI and ultrasound are examples. In fact, the application of these and other technologies to dentistry and the future direction for oral and maxillofacial imaging was the subject of the 2002 Inaugural Conference of the Coast Conference on Orthodontic Advances in Science and Technology, held in Pacific Grove, Calif.

The direction at this conference can be found in a brief description of the topics presented and the program titled "Craniofacial Imaging in the 21st Century, New Approaches, Challenges and Applications." Approximately 150 clinicians, educators, and researchers from around the world attended to discuss the future impact of imaging technology upon the practice of dentistry. Three topic categories existed: visualization, with focus upon patient modeling; simulation, the reproduction of biomechanical events to aid diagnosis and treatment planning; and therapeutics, the role of computer-assisted treatment and appliance design. 3-D volume imaging in a dental environment is key to developing the patient model.

Introduction to New Technology

Cone beam volume tomography (CBVT) is a method to produce volume imaging quicker and easier than conventional CT. The technology has been used to design CBVT systems specifically for dental imaging. These dental systems were developed in Europe and Asia. While more than 100 systems are in use worldwide, the first system wasn't commercially available in the U.S. until 2000. Once available, the technology has expanded rapidly across the country, especially in California. There are now approximately 30 of these machines in the U.S., the majority of which are centered in California. Currently, all of the dental schools in California have either direct or indirect access to this technology and students are being trained to appreciate the benefits and application of 3-D multiplane imaging for a wide variety of dental applications. The impact is such that three other CBVT systems have been developed and are either commercially available or will be soon.

The development and application of such concepts show that the future is not on the distant horizon but rather is developing in the present. Therefore, the purpose of this *Journal* issue is to familiarize the readers with the current application of CBVT 3-D volume imaging in dentistry.

The first article by Drs. Danforth, Dus, and Mah presents the four different CBVT systems developed for 3-D oral and maxillofacial imaging. It describes the basic differences between the utilized 3-D cone beam technology and medical CT, plus provides a table of comparative features for the systems. The remaining articles focus upon the clinical application of this imaging. Drs. Mah, Enciso, and Jorgenson describe how 3-D imaging is used for evaluation of palatal root resorption of maxillary lateral incisors when the neighboring canines are slow to erupt. Dr. Hatcher, Mr. Dial, and Ms. Mayorga show the application of this low patient dose technology for dental implant imaging and other imaging examinations. Drs. Erickson, Caruso, and Leggitt describe a case in which CBVT imaging helped to solve an unusual problem of lip paresthesia that developed following orthodontic movement of a mandibular molar. Lastly, Drs. Danforth, Hall, and Mr. Peck show how CBVT imaging can assist both the surgeon and patient during surgical treatment planning, risk assessment, and treatment outcomes of impacted mandibular third molars.

The contributors to this *Journal* are enthusiastic users of CBVT technology and are excited about not only the current applications of the technology, but also for the applications to come. We appreciate the opportunity to share our experiences and vision of the future. The concepts associated with the Coast Conference on Craniofacial Imaging are a reality. We hope that our participation in this *Journal* will be helpful to the readers as you become more aware and involved with the reality of 3-D volume imaging and computer patient modeling for dentistry. **CDA**

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3-D Volume Imaging for Dentistry: A New Dimension

Robert A. Danforth, DDS; Ivan Dus, MD, DDS, PhD; and James Mah, DDS, MS, DMSc

Abstract

The use of computed tomography for dental imaging procedures has increased recently. Use of CT for even seemingly routine diagnosis and treatment procedures suggests that the desire for 3-D imaging is more than a current trend but rather a shift toward a future of dimensional volume imaging. Recognizing this shift, several imaging manufacturers recently have developed 3-D imaging devices specifically for dental purposes using cone-beam computerized tomography. This technology allows for 3-D imaging similar to CT, but at lower equipment cost, simpler image acquisition and lower patient radiation dose. Herein, an overview of these devices is provided such that potential users can be better informed about this emerging technology.

Computed tomography (CT) provides valuable 3-D imaging of the dental and maxillofacial structures for diagnosis and treatment planning. In the past, such imaging has been utilized for complex surgical cases, but widespread use of CT for dental implant imaging has made it more common. Several recent reports have described additional uses of CT imaging for assessment of impacted teeth,[1,2] root configurations,[3] and mandibular condyle evaluation.[4]

CT examination is one of the most valuable medical imaging modalities available. Its use in the U.S. has risen from 5-5.5 million examinations in 1983 to more than 20 million in 1995.[5] CT examinations comprised about 2 percent of all radiographic examina-

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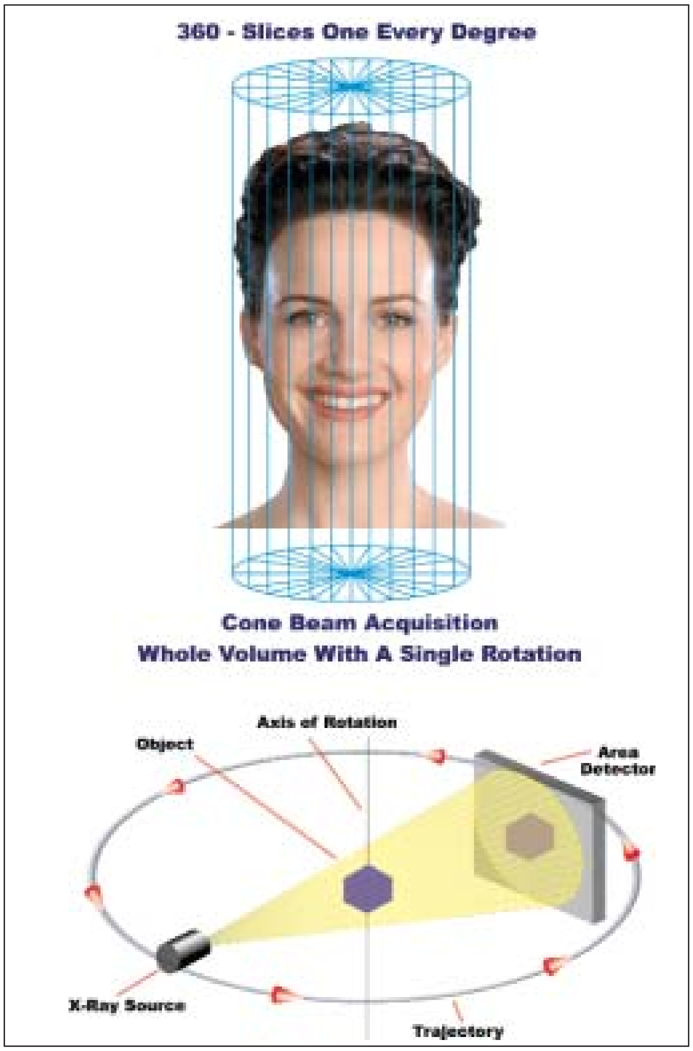

Figure 1a.

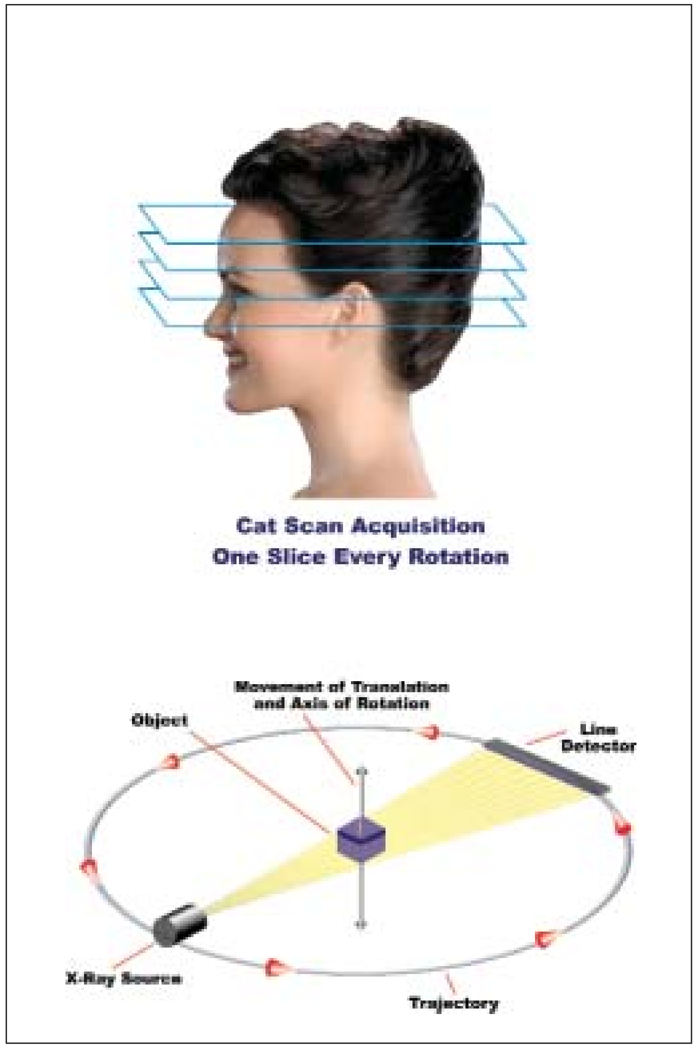

Figure 1b.

Figures 1a and b. Differences in image acquisition between cone beam volume tomography (A) and traditional computed tomography (CT) (B). *Courtesy of Dr. Ivan Dus and Dr. Carl Gugino, Aperio Services, Inc. Sarasota, Fla.*

tions in 1991 and in 2001 comprised 10 percent to 15 percent of the total.[5] If this trend in medicine is followed in dentistry, the demand for 3-D dental imaging devices can be expected to follow; hence, the development of 3-D imaging devices specifically for dental and maxillofacial use.

Currently, several machines are either commercially available or FDA approval pending. It is important to distinguish these new technologies and devices from traditional medical CT devices as they are not the same. The technology is described as either cone beam computerized tomography (CBCT), or preferred for this report cone beam volumetric tomography (CBVT). The purpose of this article is to provide an introduction to these imaging machines and describe the differences between these and medical CT. CBVT systems developed for dentistry include: Newtom QR 9000 and the upcoming Newtom Plus, (Aperio, Inc., Sarasota, Fla.), 3-D Accuitome, (J. Morita, Tokyo, Japan), MercuRay, (Hitachi, Tokyo, Japan) and

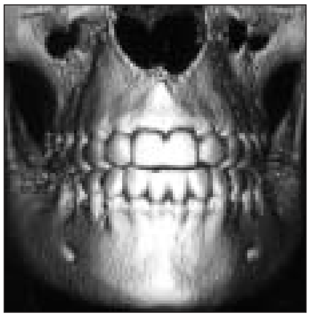

Figure 2a.

Figures 2a and b. Comparison of full maxillofacial-mandibular coverage to a regional volume. *A. Courtesy of Dr. James Mah, University of Southern California. B. Courtesy of Dr. Edgar Hirsch, Universität Leipzig, Germany and J. Morita, Irvine.*

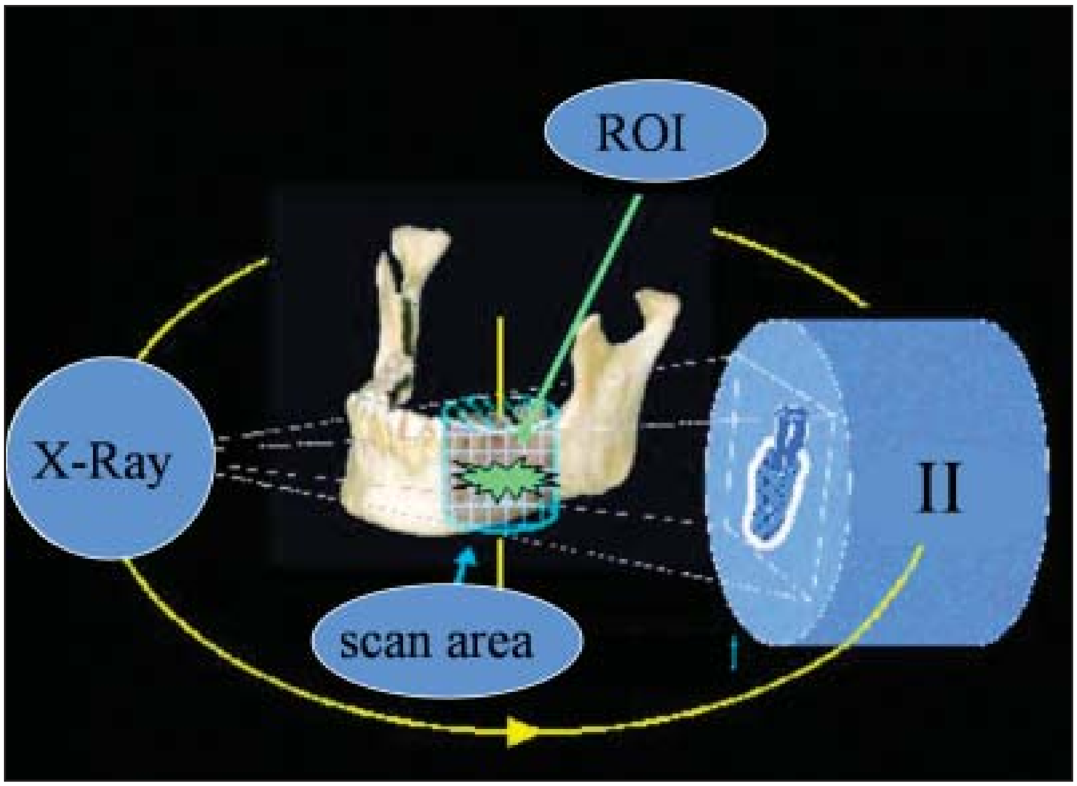

Figure 2b.

the ISI/CAT, (Imaging Science International, Hatfield Penn., and Xoran Technologies, Ann Arbor, Mich.).

Cone Beam Volume Tomography

The two principle differences that distinguish CBVT from traditional CT are the type of imaging source-detector complex and the method of data acquisition. **Figures 1a** and **1b** illustrate the basic difference between these two technologies. The X-ray source for CT is a high-output rotating anode generator while that for CBVT can be a low-energy fixed anode tube similar to that used in dental panoramic machines. CT employs a fan-shaped X-ray beam from its source for imaging and records the data on solid-state image detectors arranged in a 360-degree array around the patient. CBVT technology uses a cone-shaped X-ray beam with a special image intensifier and a solid-state sensor or an amorphous silicon plate for capturing the image.[6,7,8,9] Development of this technology dates back to the mid 1970s when it was originally devised as a cost-effective and efficient method for obtaining cross-sectional 3-D imaging for radiotherapy and later angiography.[10-13]

Conventional medical CT devices image patients in a series of axial plane slices that are captured either as individual stacked slices or from a continuous spiral motion over the axial plane. When compared to conventional CT, image capture with spiral motion is quicker and can be done at a much lower radiation dose.[14] (Although the ICRP warns that this is more so a function of the scan volume, mAs, pitch and slice width.[5]) Conversely, CBVT presently uses one rotation sweep of the patient similar to that for panoramic radiography. Image data can be collected for either a complete dental/maxillofacial volume or limited regional area of interest. Scan times for these vary from 75 to 40 seconds for the complete volume to 17 seconds for the regional. Currently, patient exposure effective dose has been determined only for the Newtom 9000 complete volume system. This can be as low as 50 µSv or in a similar range to that for a dental periapical full-mouth series using current tech-


Figure 3a.


Figure 3b.


Figure 3c.


Figure 3d.

Figures 3a–d. Models of 3D maxillofacial radiology imaging machines.
A. Courtesy Dr. James Mah, University of Southern California. B. Courtesy of Dr. Edgar Hirsch, Universität Leipzig, Germany and J. Morita, Irvine. C. Courtesy Arun Singh, Imaging Sciences International, Hatfield, Penn., Xoran Technologies, Ann Arbor, Mich. D. Courtesy Tricia Winter, Hitachi Medical Systems America, Inc., Twinsburg, Ohio.

niques.[15,16] From the perspective of radiation dosimetry, these new developments in specific CTs for dentistry are very much welcomed as radiation dose from medical CT has not decreased in the last decade while radiation dose from other forms of medical radiography has decreased by 30 percent.[5]

Although the concept of 3-D imaging for dental systems is similar to that for the medical CT scanner, the methods and terms used to describe the technology differ. The term 3-D cone beam volumetric tomography better describes the emerging dental and maxillofacial machines. Systems can be categorized as either full volume maxillo-mandibular tomography (**Figure 2a**) or regional volume tomography (**Figure 2b**). A full-volume scan encompasses the entire volume of anatomy from approximately the lower orbital rim to just below the inferior border of the mandible while the regional is confined to a portion of one dental quadrant or regional area of interest. Some machines are restricted to either one of the methods while others offer full or regional options. These are shown in **Figures 3a-d**. As can be seen, the Newtom QR 9000 images the patient in a supine position with a CT-like opening in the gantry sufficient to accommodate only the head and neck. The other units superficially have a dental panoramic machine appearance with the patient sitting upright. All acquire image data using a single 360-degree imaging rotation around the patient.

Comparative Technology

Table 1 compares specifications for these maxillofacial CBVT machines with traditional CT. As can be seen, all of the maxillofacial CBVT units share common features in regard to X-ray beam, sensor detection, X-ray exposure parameters and method of image acquisition. These are dramatically different than for CT which is designed for more extended areas of coverage. Some differences between the CBVT machines exist. Scan time varies with either the full or regional image volumes. Resolution expressed as mm3 voxel size tends to favor the regional devices. The reported effective exposure dose is associated with dental implant imaging because it is most comparable to CT. The figures listed for effective dose were provided from the manufacturer and are not truly comparable due to variables such as different size of imaging volumes and operational settings of the devices. For those machines with such data, it can be seen that effective radiation dose associated with CBVT maxillofacial imaging is greatly reduced from that of CT for similar purposes. Likewise, differences with CT exist in the safety operation of these units. Automatic exposure control adjust the amount of X-ray radiation based upon tissue density to ensure imaging data are properly collected and an emergency stop mechanism terminates the scanning process if inconsistent exposure values are detected during the operation.

A composite of representative image examples are shown in **Figures 4a-i**. As can be seen, many different image views of the patient are possible. While the common panoramic, implant, and TMJ views are present, **Figures 4a-c**, it is volumetric reformatting, **Figures 4d-i**, that demonstrate the new dimension in imaging. **Figure 4d** reveals a mandibular third molar

Table 1

Comparison of Maxillofacial CBVT Devices

Parameters	Newtom 9000	Newtom Plus	3DX Accuitomo	ISI/CAT	Hitachi MercuRay	MedicalCT
X-ray beam	cone	cone	cone	cone	cone	fan
Sensor detector	area	area	area	area	area	linear
	image intensifier CCD	image intensifier CCD	image intensifier CCD	amorphous silicon flat-panel detector	image intensifier CCD	Solid state or gas
Grayscale	8 bit	12 bit	8 bit	12 bit	8 bit	12 bit
Voxel size (mm^3)	0.265	0.07-0.20 (variable)	0.125	0.4 typical 0.2 minimum	0.1	0.3[16]
X-ray source			direct current	direct current		
anode	fixed	fixed	fixed	fixed	fixed	rotating
kVp range	110 (fixed)	110 (max)	60-80	120	70-100	110-140
mA	10 15 max		1-10	1-3	to 15 max	80-300
Image acquisition	panoramic type	panoramic type	panoramic type	panoramic type	panoramic type	axial slices
	single 360°	single 360°	single 360°	single 360°	single 360°	multiple 360°
	rotations	rotations	rotations	rotations	rotations	rotations
Patient position	supine	supine	seated	seated	seated	supine
Image area	maxillofacial	maxillofacial	maxillofacial	maxillofacial	maxillofacial	entire body
Dimensions (cm)	13x13 (height x diameter)	22x25 (height x diameter)	3.0x4.0 (height x diameter)	2 versions 11x17 17x17 (height x diameter)	D mode 5.12 P mode 11.7 C mode 15.0 (height only)	varies/exam
Imaging session (sec)	75	30 or less	17	40 or less	9.6	varies/exam
Effective dose* (max_& mand) mSv	.04-.05[15]	.01-.02	.0074	not available	not available	.289 low[17] .723 high[17]
Auto exposure control	smart scan yes	smart scan yes	no	not reported	not reported	no
Commercially available	yes	end of 2003/early 2004	yes	projected 2004	not reported	yes

*Effective dose as reported is provided from the manufacturer and is not truly comparable to other devices due to variable such as different size of imaging volumes and operational settings of the devices.

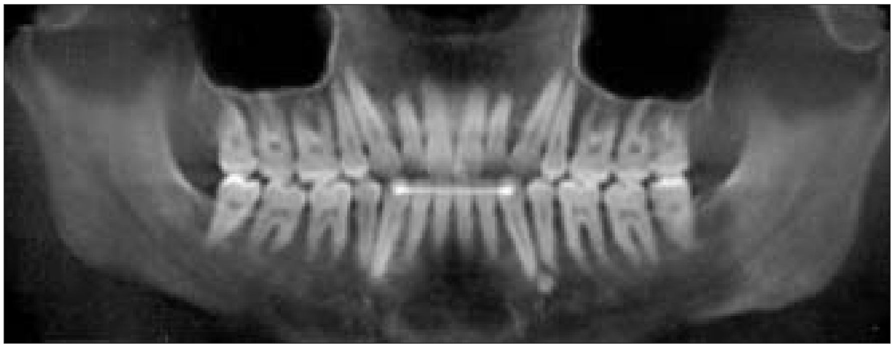

Figure 4a.

Figures 4a–i.

Representative examples of volumeimaging using maxillofacial CBVT machines. A: Reconstructed panoramic. B: Cross-sectional mandibular nerve canal. C: TMJ images. D: Impacted molar- nerve canal. E: Bimaxillary cross-section. F: Airway- sinus, nasal fosse. G: Upper airway, lateral view. H: Supernumery teeth. I: Root configurations.

Courtesy of Redmond Imaging Center, University of Southern California. Courtesy of Dr. Edgar Hirsch, Universität Leipzig, Germany and J. Morita, Irvine. Courtesy of Arun Singh, Imaging Sciences, Hatfield, Pa.,Xoran Technologies, Ann Arbor, Mich.

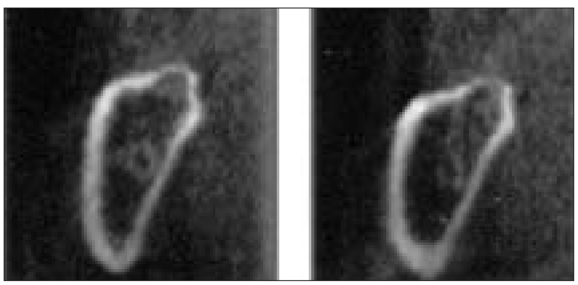

Figure 4b.

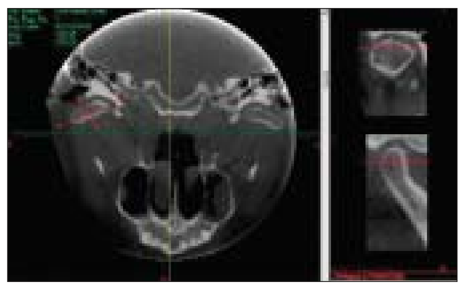

Figure 4c.

Figure 4d.

Figure 4e.

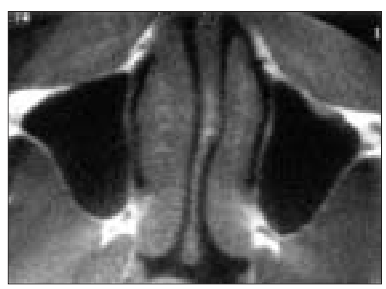

Figure 4f.

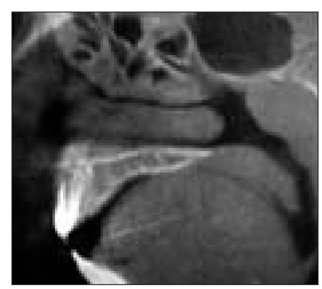

Figure 4g.

Figure 4h.

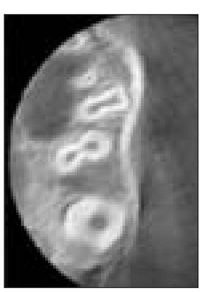

Figure 4i.

and its relationship to the inferior alveolar canal; **Figure 4e** is a cross-sectional arch view; **Figures 4f-g** are representative of the many possible airway images; **Figure 4h** shows a supernumerary tooth; and **Figure 4i** shows root configurations and spatial relationships. Each of these images is but one of many that comprises the 3-D volume for any anatomical area being examined. In addition, computer-generated models can be reconstructed from the initial imaging data. Examples are shown in **Figures 5a-d**. The posterior palatal/lingual view, not readily available with traditional dental radiography, is demonstrated in **Figure 5b**. Views from the posterior are unique to volume imaging and offer the possibility to replace viewing stone models for this function.

Summary

Four CBVT 3-D imaging systems have been recently developed for dentistry. Multiple image views, various measurement analysis, and computer-

Figures 5a-d. Computer-generated models from reconstructed image data.
Courtesy of Redmond Imaging Center, University of Southern California School of Dentistry.

generated patient models, all of which allow the diagnostician to better visualize in a "spatial plane concept" potential therapeutic procedures before they are actually rendered is perceived as the next progressive step in dental imaging. While primarily intended for dental implant imaging, Figures 4 and 5 show the different aspects of dental diagnosis that could benefit from 3-D imaging.

This progressive step does not mean 3-D imaging will replace traditional radiology. There are some factors to consider when deciding whether or not 3-D imaging should be used. Image resolution for 3-D imaging is less than film. The machines are expensive ranging from $200,000 to $300,000 and are generally available only in imaging centers or larger dental practices. This reduces patient access and the cost of the imaging examination is usually greater than for film. Patient radiation dose is lower than for conventional medical CT, but is similar to that for standard dental radiology. This would be an advantage for dental implant patients but not necessarily for others. Not all imaging examinations will be successful. No patient movement is critical for success and patients unable to comply are not candidates for 3-D imaging. Also, there will be a learning curve for dentists unfamiliar with reading multiple plane images.

Despite these limitations, there is a role for this technology. CBVT imaging can provide a much-needed 3-D perspective in certain cases that require more information than can be obtained from traditional radiography. Examples of applications of CBVT in diagnosis and treatment planning are in dental implant placement, TMJ conditions, jaw tumors, airway analysis, impacted teeth, periodontal or endodontic problems.

This article provides a brief introduction to these emerging machine so that any potential user can be better informed about the differences between these and traditional CT. CDA

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Cone Beam CT for Pre-Surgical Assessment of Implant Sites

David C. Hatcher, DDS, MSc; Craig Dial, DRT; and Camille Mayorga, DRT

Abstract

The pre-surgical assessment of proposed implant sites requires very specific and accurate data. Imaging has always been used to assist with the implant site assessment but until the recent introduction of cone beam CT scanners, the available imaging had a low value when considering the ratio between diagnostic potential, cost of study, and risk to the patient. CBCT scanners are nearing the end of their first-generation dedicated maxillofacial imaging modalities and have proven to be an extremely useful imaging tool for pre-surgical assessment of implant sites. CBCT scanners are easy to use and produce a 3-D image volume that can be reformatted using software for customized visualization of the anatomy. Protocols have been developed that optimize the visualization of image for implant site assessment.

Anatomic and prosthetic factors are considered by the clinician to determine the best implant placement sites. Implants need to be placed where they have the best chance for success. The implant not only needs to be located in an area of a missing tooth but the implant needs to be placed in a way to satisfy restorative, esthetic, biomechanical and functional requirements (prosthetic considerations). Imaging can be used to determine status of the anatomy in the proposed implant site and how to best optimize the implant placement considering the prosthetic needs and anatomic constraints. An imaging stent can be used to provide detailed feedback relat-



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Figure 1. An image volume can be reformatted and displayed in multiple planes using software tools. The patient's anatomy has been reformatted in axial (upper left), sagittal (upper right), coronal (lower left) and transaxial planes (lower right). Selected anatomy has been labeled as follows: Maxillary Sinus (MS), Nasal Fossa (NF), Mental Foramen (MF), Mandibular Canal (MC), Sphenoid Sinus (SS), Incisive Canal (IC) and Hard Palate (HP).

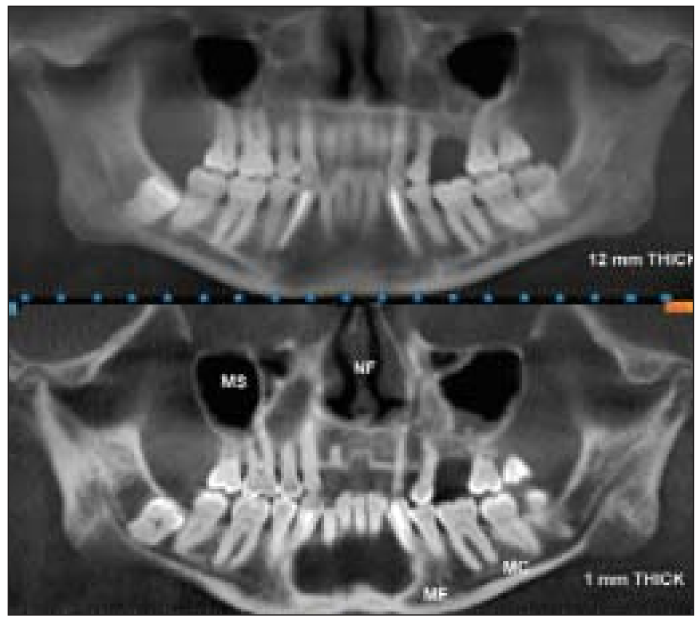

Figure 2. The maxillofacial structures have been reformatted and displayed in curved planes of variable thickness resembling a panoramic view. The upper image is 12 mm thick (buccolingual) and the lower image is 1 mm thick. Selected anatomy has been labeled as follows: Maxillary Sinus (MS), Nasal Fossa (NF), Mental Foramen (MF) and Mandibular Canal (MC).

ing the prosthetic and anatomic considerations. Determining the relationships between the anatomic and prosthetic considerations leads to the development of a set of imaging goals and the methods required for achieving the desired imaging outcome. Ideal imaging studies are the successful fulfillment of goals derived to solve specific clinical problems.

There is a wide spectrum of imaging options requiring a thoughtful strategy to select imaging techniques that produce optimum diagnostic information. The ideal imaging modality produces the desired diagnostic information while minimizing the cost and risk to the patient.

The purpose of this article is to introduce volumetric imaging (cone beam CT) for pre-surgical assessment of implant placement and to compare this technique with other available imaging techniques.

Imaging Goals

General Imaging Goals

Once the implant sites have been determined, then the imaging strategies and goals can be developed. In all cases, the replacement of the missing teeth involves restoring a portion or all of the occlusion and therefore there may be anatomic interests that extend beyond the implant site. This may be an important consideration when determining the imaging strategy. For example, do you want the region of interest extended beyond the implant site to include all components of the articulation, such as the opposing arch, maxillomandibular spatial relationships and temporomandibular joints (TMJs)? Imaging can be used by the clinician to understand the anatomic foundation for placing the implant and restoring the occlusion.

- Image the entire region of interest (ROI)
- View the ROI in at least 2 planes at right angles to each other (3D perspective)

■ Obtain images with maximum detail, minimal distortion and minimal superimposition

■ The diagnostic value of the imaging study must be in balance with the cost and risk associated with obtaining the study.

Implant Site Assessment Imaging Goals

For each implant site, the following anatomic considerations may allow the clinician to determine the best site for the implant and meet the prosthetic goals.

■ Determine bone height and width (bone dimensions).

■ Determine bone quality

■ Determine long axis of alveolar bone

■ Identify and localize internal anatomy

■ Determine jaw boundaries

■ Pathology detection

■ Transfer of radiographic information

Bone Dimensions

Bone height and width allow the clinician to determine how much bone is available in the proposed implant site.

Bone Quality

Dynamic loading of an implant imparts forces to the adjacent bone. There is an assumption that bone density is directly proportional to load-bearing capacity of the bone and that implant failure is associated with low bone density.[8] The architecture of the supporting bone is also a factor associated with the functional capacity of these tissues. Dynamic loads received by the implants may strain the supporting bone and induce changes

Figure a.

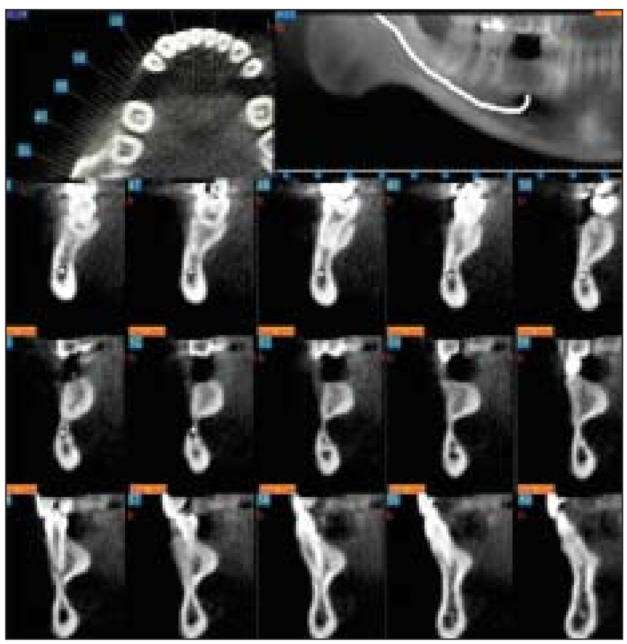

Figure 3b.

Figures 3a–c. These images are for a 25-year-old male with congenitally missing mandibular second bicuspids. The sites are being evaluated for feasibility of implant placement. The clinical photographs show the edentulous sites and suggest the presence of adequate vertical and buccolingual alveolar bone volume to place implants. The CBCT scan reconstructed in 3-D, axially and transaxially, showed a large lingual concavity that would severely limit implant placement.

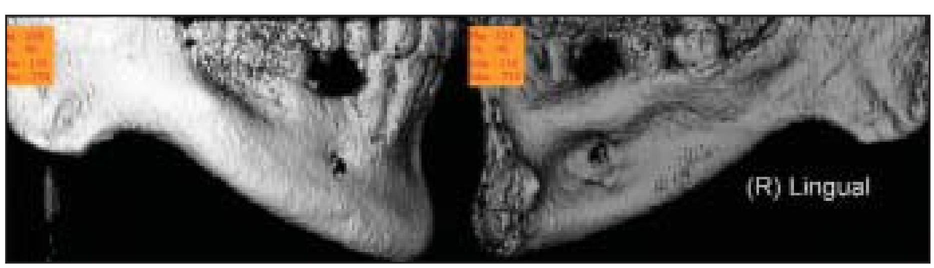

Figure 3c.

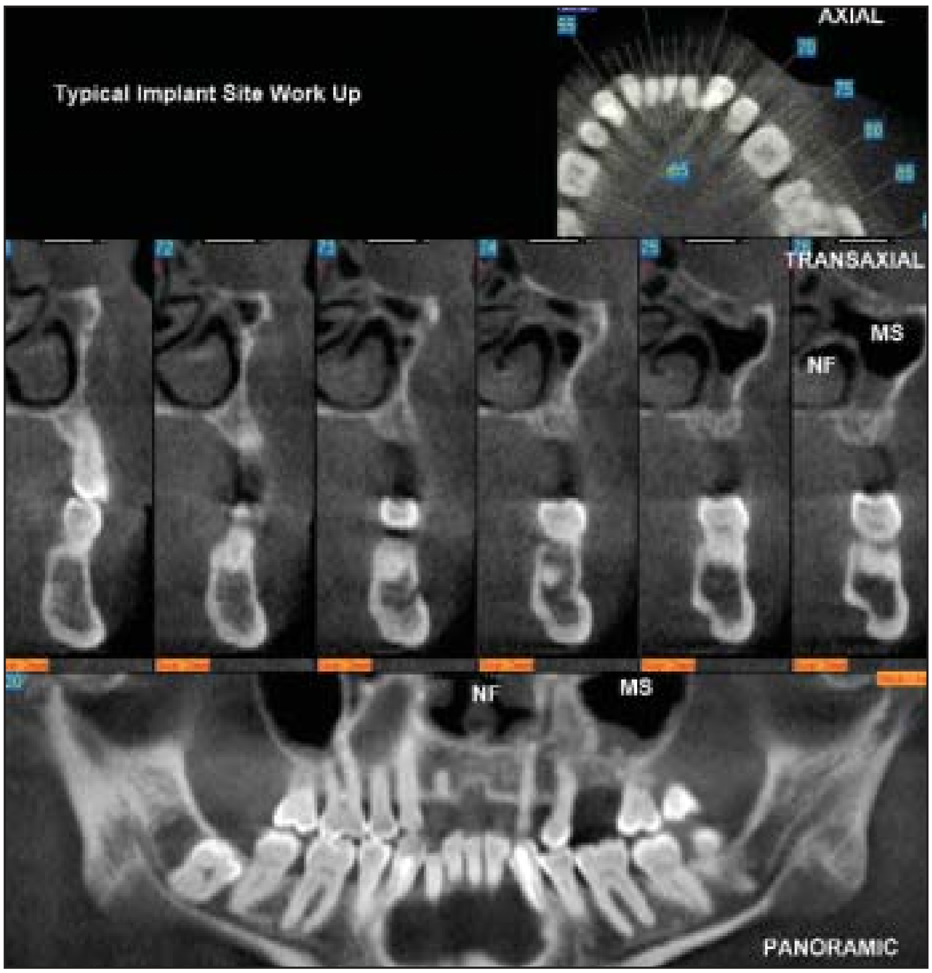

Figure 4. This is an implant site workup for missing tooth #14. The axial projection (upper right) is used to map the jaw curve to create the curved (panoramic projection). The jaw curve is also used to map out the location of the transaxial sections (center panel). The transaxial sections are created perpendicular to a tangent created at the desired point on the jaw curve.

in that bone. Bone requires a certain amount of strain for maintenance, but excessive strain may cause fatigue failure of the trabeculae.

Long Axis of the Alveolar Bone

Axis orientation describes the angle formed by the vertical long axis of the alveolar-basal bone complex when viewed in cross-section. Information about the axis orientation is important for successful alignment of the implant within the boundaries of the jaws. Determining the long axis of the alveolar bone allows the clinician to optimize the trajectory of implant placement with the emergence profile and loading characteristics of the implant (**Figures 1, 3a-c, 4**).

Internal Anatomy

The most common internal anatomy to be identified and localized includes the mandibular canal, maxillary sinus, nasal fossa, mental foramen, incisive canal, and adjacent teeth. Identifying these structures aid the clinician in determining the boundaries for implant placement (**Figures 1, 2, 4**).

Jaw Boundaries

Imaging can be used to identify the outer boundary of the jaws including impressions into the jaws, such as fossae (**Figures 1, 3a-c, 4**).

Pathology Detection

Jaw pathology in the proposed implant site or within the maxillofacial regions is important to detect, diagnose, treatment plan, and treatment sequence. Abnormalities involving the alveolar ridge include retained root tips, inflammatory processes, cyst, and tumors. In addition, anomalies involving other maxillofacial structures such as maxillary sinuses and TMJs may complicate the successful implant process. For example, changes in stress (force/area) directed at poorly adapted TMJs may increase TMJ symptoms. Changes in TMJ stress levels may result from operative manipulations, changes in masticatory abilities and changes in vertical dimension or maxillomandibular spatial relationships (**Figures 5a-d, 7a-d**).

Transfer of Radiographic Information (Communication)

The diagnostic and treatment planning information gained during image analysis may need to be transferred. For example, the restorative dentist may have performed the original image analysis, made decisions about the precise placement location for implants and now wants to convey the information to a surgeon and/or patient. Images and derivative information can be used for downstream communication and knowledge transfer (**Figures 6a-c**).

Imaging Options

Several imaging modalities have been used for the pre-surgical evaluation of implant sites. **Table 1** is a comparison matrix showing the relative value of the commonly available 2- and 3-D imaging modalities.[1-15] The panoramic, periapical and cephalometric images contain superimpositions, have large information voids related to depth, and are affected by projection geometry so that measurements are not reliable. Only tomography, conventional CT scans, and cone beam CT scans provide the information desired about each implant site. When the imaging goals are extended to occlusion, maxillomandibular spatial relationships and

Figure 5a.

Figure 5b.

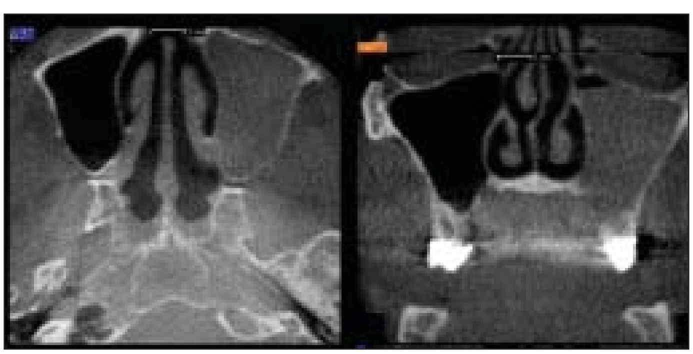

Figure 5c.

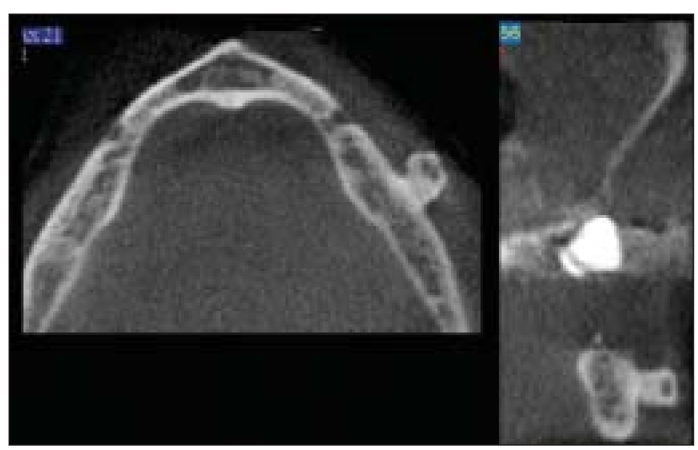

Figure 5d.

Figures 5a–d. This sequence of images was prepared for a 64-year-old male in the planning phase for mandibular posterior implants. A single CBCT scan created the opportunity to evaluate the proposed implant sites and the remainder of the maxillofacial region. In this case, the following relevant information was acquired from the CBCT: left side maxillary sinusitis with an occluded osteomeatal complex, benign tumor (osteoma) extending from the buccal surface of the left side of the mandible, degenerative joint disease involving the left TMJ, over-eruption of the maxillary posterior teeth, and the maxillomandibular spatial relationships.

Table 1

Valuation of Implant Imaging Techniques

Imaging Goal	2D Sources Caphalometric	Tomographic	Panoramic	Periapical	3D Sources CT	Cone Beam CT
Bone height	★	★★★	★★	★★★	★★★★	★★★★
Bone width	–	★★★	–	–	★★★★	★★★★
Long axis or ridge	–	★★★	–	–	★★★★	★★★★
Identify internal anatomy	★	★★★	★★	★★★	★★★★	★★★★
Localize anatomy	★	★★★	★	★	★★★★	★★★★
Determine jaw boundaries	–	★★★	★★	–	★★★★	★★★★
Pathology detection	★	★★	★★★	★★	★★★	★★★
Bone quality	–	★★	★★	★★	★★★★	★★★
Communication	★	★★	★★	★	★★★★	★★★★
Anatomy overview	★★	★	★★	★	★★★	★★★★
Benefit/risk/cost ratio	★	★★★	★★	★	★★★	★★★★

Table 1 shows a list of commonly used imaging techniques and associated imaging goal. The relative application value for each imaging technique has been rated as follows:

– = No Value ★ = Low Value ★★ = Moderate Value ★★★ = High Value ★★★★ = Highest Value

the temporomandibular joint then cone beam CT scans stand alone as the best value.

Volumetric Imaging

Volumetric imaging (VI) or cone beam CT (CBCT) creates the opportunity to extend the information yield beyond the conventional imaging methods and is an ideal modality for implant planning. CBCT produces accurate 3-D image data. The field of view is scalable and one scan can include the entire maxillofacial region including the maxilla, mandible, base of skull and TMJs. Currently, the Newtom 9000 is the only available CBCT unit in the North America and is being distributed by Aperio Services. This unit has a voxel size of approximately 0.3 mm.[3] The small voxel size would allow feature detection size and dimensional accuracy in the range of 0.5 mm. A single cone beam CT scan contains enough information to satisfy the imaging objective stated above including maxillomandibular spatial relationships.

Software is used to display and visualize the anatomy in a way that is clinically meaningful. The software allows for multiplanar reformation and display. The primary reconstruction of the raw data is completed parallel to the occlusal plane and therefore the occlusal plane is used as the visualization reference plane. The reconstructions can occur in the axial, coronal, sagittal, curved, and oblique planes (**Figures 1, 2, 4**). The location, dimensions and thickness of the reconstructions can be varied to achieve the desired results (**Figure 2**). The manufacturers of CBCT scanners offer software that is capable of multiplanar reformations but third-party software is also available to import and manipulate image data that has been exported in a DICOM format. Third-party software includes Materialise Simplant and Nemotec Dental Systems.

Summary

The introduction of cone beam CT creates the opportunity for clinicians to acquire the highest quality of diagnostic images with an absorbed dose that is comparable to other dental surveys and less than a conventional CT.[16] The large field of view and 3-D image set offered by CBCT creates the opportunity for the clinician to adequately assess the implant site, look at the opposing occlusion, TMJs, and other factors that may associated with the total success of implant-based rehabilitation of the patient's occlusion (**Figures 5a-d, 7a-d**).

The next generation CBCT scanners available by the first quarter of 2004 will have improved capabilities that include a reduction in voxel size from 0.3 to 0.1 mm,[3] increased number of gray levels from 256 to 4096 shades, faster scan times down to 10 seconds, and larger field of view up to 9-inch diameter. The proposed improvements will increase the image quality, diagnostic potential, and increase the value of the study to the patient and clinician (**Figure 8**).

CBCT first became available in the United States in May 2001 and the number of CBCT scanners in California exceeds the combined total for the remainder of the states. Most of the CBCT scanners are located in universities and dental imaging centers, and are available by referral to the dental community. **CDA**

Figure 6a.

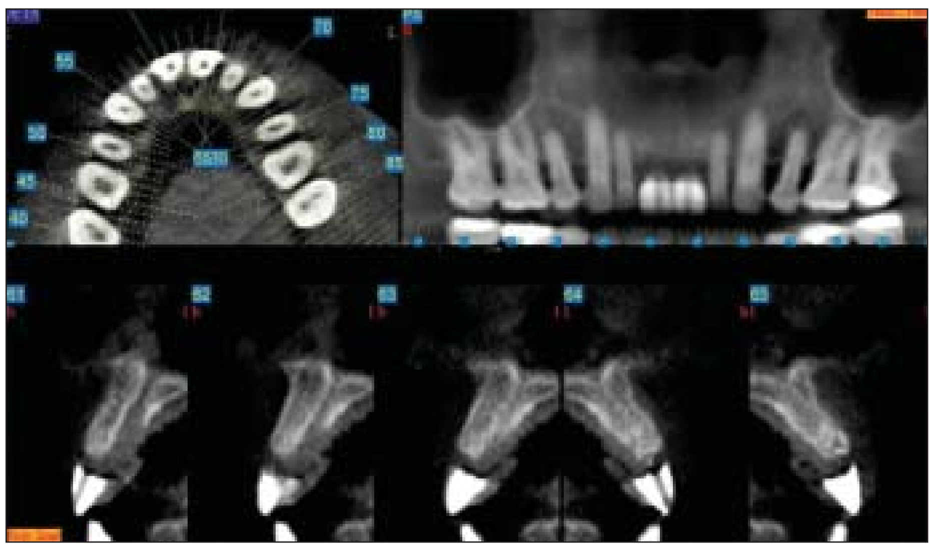

Figure 6b.

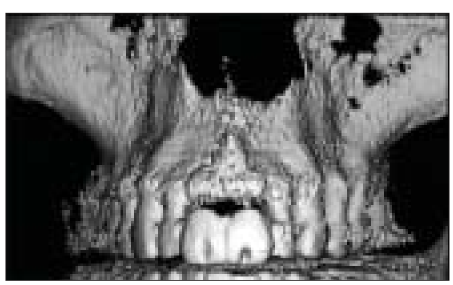

Figure 6c.

Figures 6a–c. A 56-year-old male missing teeth #s 8 and 9 had a CBCT scan with a radiographic stent in place. Opaque teeth were fabricated and positioned to simulate their desired final size and position. A hole drilled down the long axis of the teeth identifies the trajectory of the implant placement and to serve as surgical guides. The stent can be used as a reference for radiographic planning and to transfer the simulation product to the mouth.

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Figure 7a.

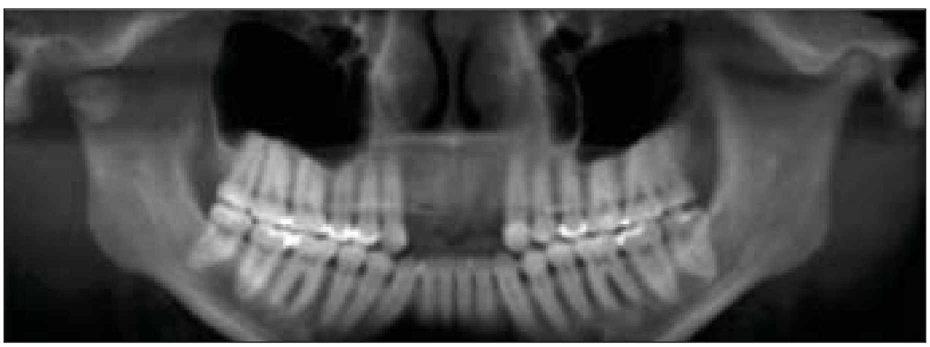

Figure 7b.

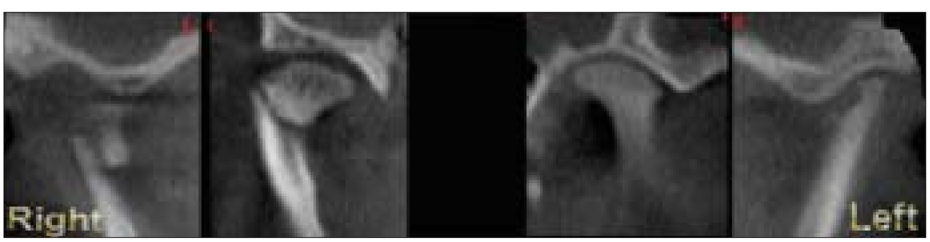

Figure 7c.

Figures 7a–d. This series of images belong to a 19-year-old female who traumatically lost teeth #s 7-10. A typical implant work up would be isolated to the implant site (axial, transaxial, panoramic views) and allow for determination of the bone height, width, and quality. With CBCT there is more information available including the opposing occlusion and the TMJs. Evaluation of the TMJs showed left side degenerative joint disease and a right side sub-condylar fracture dislocation.

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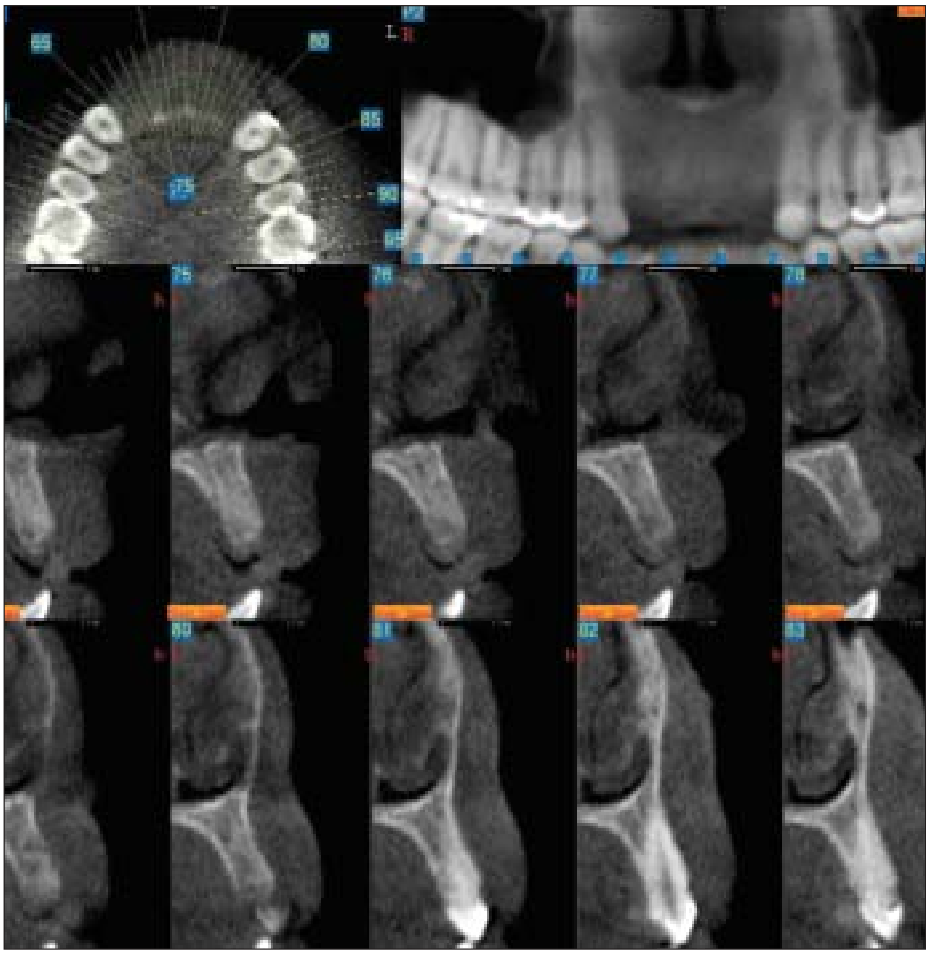

Figure 7d.

Figure 8: Newtom 9000 Plus, next-generation CBCT, showing a larger field of view, facial soft tissue, and orthographic cephalometric rendering.

Management of Impacted Cuspids Using 3-D Volumetric Imaging

James Mah, DDS, MS, DMSc; Reyes Enciso, PhD; Michael Jorgensen, DDS

Abstract

Management of impacted cuspids is a complex clinical problem involving proper assessment and interdisciplinary treatment planning. In this paper, we describe the use of 3-D volumetric imaging in the management of impacted cuspids and illustrate this application in case reports of maxillary and mandibular impacted cuspids.

Impacted cuspids are a relatively common occurrence and with the exception of third molars, the maxillary canine is the most frequently impacted tooth.[1,2] The mandibular canine is much less commonly a concern as it is 10 times less frequently impacted.[2-4] The prevalence of impacted maxillary canines ranges from 1 to 3 percent.[2,4-7] and is more often impacted palatally (85 percent) than labially (15 percent).[2-4] Impacted canines can lead to the resorption of neighboring permanent teeth, particularly the lateral incisors. Various degrees of resorption of the permanent incisors have been reported and it has been found to occur with approximately 12 percent of impacted maxillary canines.[8] Additionally, resorption can be difficult to diagnose with conventional methods, especially if the canine is located in a direct palatal or buccal position relative to the incisor roots.[9]

Clinical evaluation of impacted cuspids involves assessment of several factors that influence the overall treatment and prognosis (**Table 1**): confirmation of presence or absence of the cuspid, length and stage of root formation, size of eruption follicle, inclination of the long axis of the tooth, relative buccal-lingual position of the tooth, amount and quality of bone covering the tooth, proximity and resorption of roots of adjacent teeth, condition of adjacent teeth, local anatomic considerations (such as the mental nerve in the case of mandibular impacted cuspids and the type of mucosa covering the impacted tooth), and the overall stage of dental development.

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Assessment of these factors can be challenging with conventional radiographic methods, due to limitations of 2-D imaging. Superimposition of structures on the film can make it very difficult to distinguish details.[2] Distortion and projection effects are also encountered with conventional radiographs. Studies have shown that panoramic films alone fail to reliably differentiate the position of impacted maxillary cuspids from the palatal or buccal.[10] For these reasons, a combination of radiographic films is often used to supplement one another. One of these combinations uses the parallax method, wherein a second occlusal radiograph is taken with the x-ray tube shifted either horizontally or vertically relative to the first exposure.[11] A more effective combination uses a panoramic and an occlusal view wherein the occlusal view is taken with an additional 10 degree inclination.[11] The occlusal view is normally taken at 60 to 65 degrees to the occlusal plane, therefore this occlusal view is taken at 70 to 75 degree inclination.[11] Recently, computed tomographic scanning (CT) has been utilized as it is capable of providing more reliable information compared to conventional methods.[9,12] CT provides excellent tissue contrast, eliminating blurring and overlapping of adjacent teeth[2] and offers orthogonal views eliminating projection effects. Additionally superimposing structures can be selectively cropped from the image to allow for improved visualization. Despite its advantages, until now, the use of CT for location of impacted teeth and assessment of resorption has been restricted.[13] In recent years, 3-D volumetric imaging has been developed specifically for dentistry (see other papers in this issue for detailed descriptions). In addition to the advantages of CT, these technologies offer reduced cost relative to medical CT and significantly reduced radiation exposure. The absorbed dose from a dental volumetric imaging session is 50.3 µSv (Newtom 9000),[14] while that of a dental panoramic film ranges from 2.9-9.6 µSv[15] and a complete mouth series ranges from approximately 33 to 84 µSv[15] and 14 to 100 µSv,[16] depending upon variables such as film speed, technique, kVp, and collimation.

Surgical/Orthodontic Management

In order to begin applying orthodontic forces to impacted teeth, it is generally necessary to gain access by means of surgical intervention. Depending upon the degree of impaction, this may involve removal of soft tissue only or a combination of soft tissue and bone. A diagnosis and treatment plan is formulated based on data obtained by clinical and radiographic examination. It is not only necessary to provide access for hardware placement but is also important to consider the esthetic consequences of the surgical procedure, particularly when the impacted tooth is in a labial position.[17-20] In addition to establishing the appropriate access to reach the tooth, pre-surgical planning should include a periodontal diagnosis with attention to the width and thickness of keratinized gingiva. When the impacted tooth is exposed, approximately two thirds of the crown should be uncovered[21] taking care to avoid exposure of the cementoenamel junction.[19] In some cases, this may be accomplished by performing a simple gingivectomy. Where minimal keratinized tissue exists, an apically positioned flap may be indicated when a labial approach is utilized.

When the impaction is within the alveolus, an open or closed technique may be used, and consideration must be given to contiguous vital structures. In the closed technique, full-thickness flap reflection and ostectomy are performed to expose the crown, a button attached to a gold chain is bonded to the crown and the flap is replaced. As traction is applied to the chain, the tooth then erupts through the soft tissue. In the open technique, soft tissue and bone are removed and the crown remains ex-

Table 1

Ten Clinical Factors to Consider in the Assessment of Impacted Cuspids

1. Confirmation of presence or absence of cuspid
2. Length and stage of root formation
3. Size of eruption follicle
4. Inclination of the long axis of the tooth
5. Relative buccal-lingual position of the tooth
6. Amount and quality of bone covering the tooth
7. Proximity and resorption of roots of adjacent teeth
8. Condition of adjacent teeth
9. Local anatomic considerations
10. Overall stage of dental development

Figure 1.
Panoramic, periapical and maxillary occlusal radiographs.

posed, allowing a button or bracket to be bonded after healing. The open technique avoids potential difficulties in bonding during the surgical procedure, permits rebonding if necessary without surgical re-entry, and allows direct visualization of the tooth during initial movement.[22] The closed eruption technique may reduce post-operative discomfort and may have a more esthetic outcome than the more radical surgical exposure of the crown,[17] although the open or radical exposure technique has been reported to produce satisfactory outcomes.[23] Orthodontic treatment time may be reduced for the radical exposure technique, though differences between this method and the closed eruption technique are minimal and may not be clinically significant.[22,24] Regardless of the surgical modality, it is essential to utilize a minimally invasive procedure in order to reduce the risk of damage to adjacent vital structures. This goal can best be accomplished when the precise location of the impacted tooth is determined prior to performing the surgery. Post-operative attention to plaque control and close monitoring of periodontal conditions will optimize both functional and esthetic outcomes.[25]

The following cases illustrate the diagnosis, treatment planning, surgical intervention and orthodontic management of maxillary and mandibular impacted cuspids.

Cases

Case No.1: Bilateral Maxillary Cuspid Impactions

A 13-year-old Hispanic male presented for orthodontic treatment with a diagnosis of Class I malocclusion with bilateral unerupted maxillary cuspids. Clinical examination and panoramic, periapical and occlusal radiographs indicated that the impacted teeth were within the alveolus and resorption was evident on the apices of both lateral incisors. However, it was not possible to determine the proximity of the crowns to the buccal and palatal cortical bone (**Figure 1**). Volumetric imaging was then obtained, providing the additional data necessary to plan minimally invasive surgical intervention while avoiding contiguous vital structures (**Figure 2**). Buccal mucogingival flaps were reflected, ostectomy was performed over the crowns of the cuspids, dental follicles were enucleated and flaps were apically positioned with 4-0 gut suture to expose the crowns of the impacted teeth (**Figure 3**). Periodontal dressing was placed, the patient was asked to avoid contact with the sites, and acetominophen with codeine was prescribed for analgesia. Healing occurred uneventfully and in five days the dressing was removed. The sites were gently debrided and swabbed with 10 percent povidone iodine. Twelve days after the surgical exposure, orthodontic brackets were bonded to the maxillary dentition and force was initiated (**Figure 4a**). Additionally, the four maxillary incisors were bonded together on the lingual with composite resin (Transbond LR, 3M-Unitek, Monrovia, Calif.) to dis-

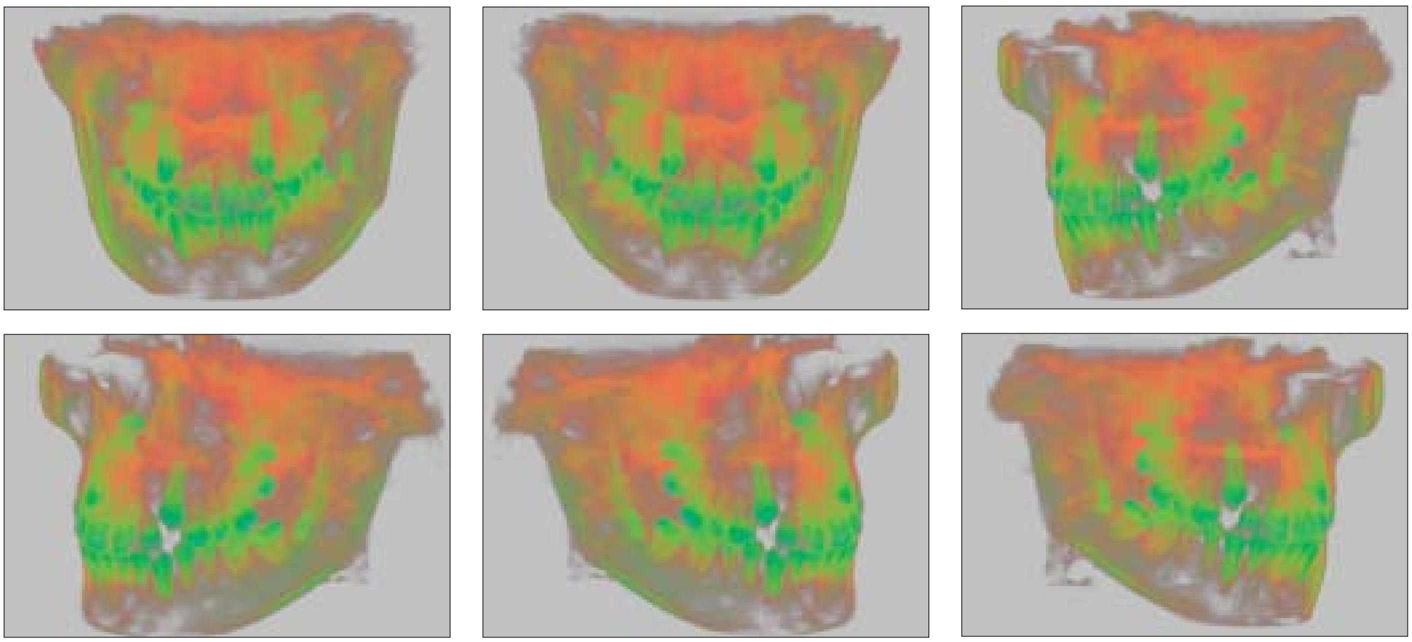

Figure 2. Volume rendered images of the impacted maxillary cuspids.

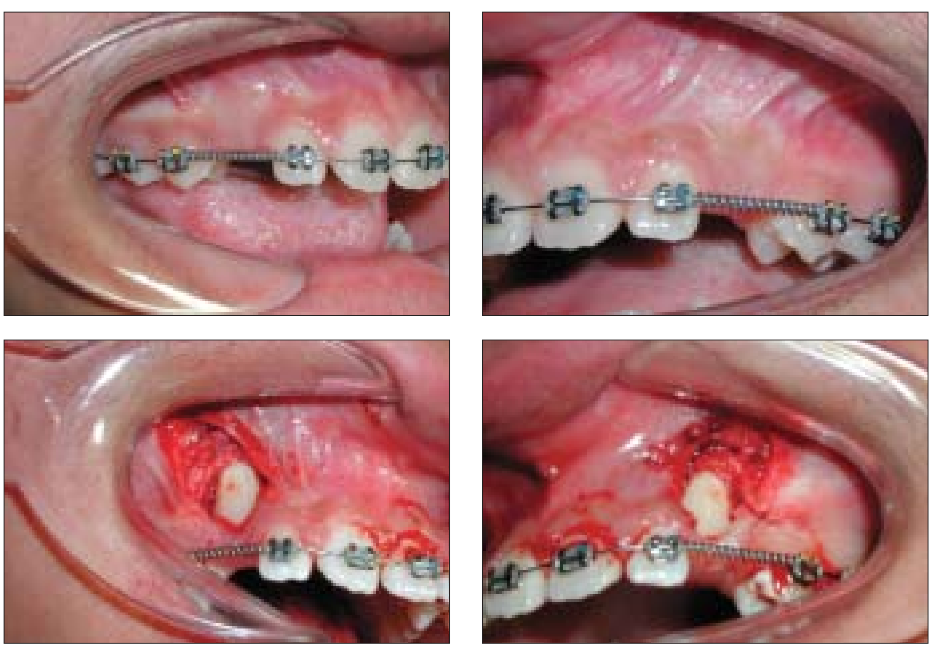

Figure 3. Surgical exposure of impacted cuspids.

tribute forces over the four incisors and prevent increased forces on the compromised lateral incisors. Subsequently, archwires were changed and orthodontic adjustments performed. The cuspids were successfully brought into alignment after four months of treatment (**Figure 4b**) and treatment is nearing completion at eight months (**Figure 4c**). Follow-up periapical radiographs of the lateral incisors showed no further root loss (**Figure 5**).

Case No. 2: Impacted Mandibular Cuspid.

An 11-year-old Hispanic male presented for orthodontic treatment with a diagnosis of Class II malocclusion with an unerupted mandibular right cuspid (**Figure 6**). Clinical examination also revealed significant mesial tipping

Figure 4. Orthodontic appliances and alignment of cuspids.

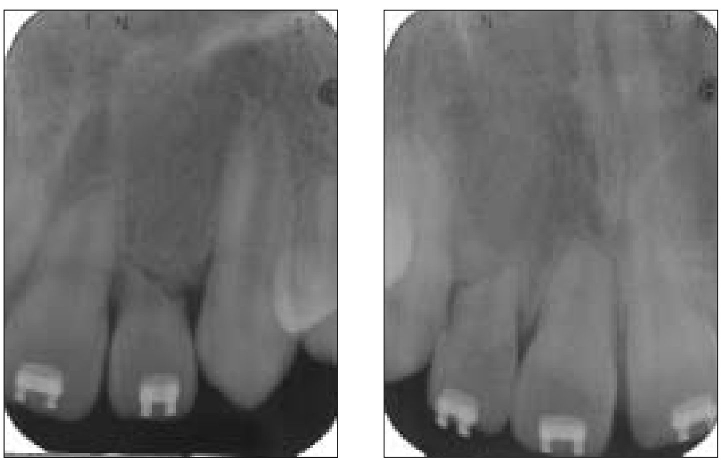

Figure 5. Follow-up periapical radiographs of cuspids.

of the mandibular right first and second premolars. Two-D radiographs indicated that the mandibular right cuspid was impacted in a distoangular orientation (**Figure 7**). Volumetric imaging was performed in order to more precisely determine the orientation of the impacted tooth and its proximity to adjacent tooth apices and the mental foramen (**Figure 8**). The patient and parent were advised of possible post-operative paresthesia due to proximity of the tooth and dental follicle to the mental foramen. Although within the alveolus, the crown of the cuspid was buccal to the apex of the first bicuspid. Therefore a buccal flap was reflected, ostectomy performed, the dental follicle drained and enucleated, and the crown of the cuspid was exposed. After bonding a gold button and chain, the soft tissue flap was replaced with 4-0 vicryl sutures, a mandibular removable orthodontic appliance was inserted, and the chain was tied to a spring on the appliance. Since the impacted cuspid crown was in close proximity to the apices of the premolars, it was decided to move the cuspid away from this area prior to placement of fixed appliances. Additionally, the mesial angulation of the premolars and the less-than-ideal condition of the first molar on the right side (stainless steel crown and endodontic treatment) left limited options for biomechanical therapy. The patient and parent were advised that the appliance must not be removed for the next five days. Ibuprophen 800 mg was prescribed for analgesia. After five days, the sutures were removed and healing was uneventful with minimal discomfort and no paresthesia. The appliance was adjusted at one- to two-week intervals over a period of five weeks until the cuspid crown was well away from the apices of the premolars. Fixed orthodontic appliances were placed in the mandible and archwires were placed (**Figure 9**). At this time, the mandibular right molar fractured vertically and was removed. Four months later, the cuspid is nearing alignment into the arch and the second molar is being brought into the position of the first molar (**Figure 10**).

Summary and Conclusions

Management of impacted cuspids is often extremely challenging for both the orthodontist and the surgeon. It is

Figure 6. Clinical photographs of unerupted cuspid and mesial tipping of premolars.

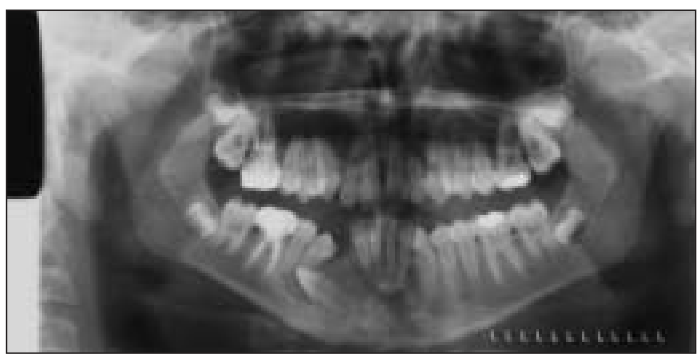

Figure 7. Panoramic image of impacted cuspid and tipped premolars.

not only necessary to formulate a treatment strategy that will allow movement of the teeth into ideal positions, but also essential to expose the teeth with minimal adverse effects on contiguous structures. In some cases clinical examination and palpation provide sufficient information to properly plan the surgical approach; in others, a combination of various 2-D radiographic images and clinical examination may be adequate.[26]

For many patients, however, the additional information obtained from 3-D imaging is invaluable in planning an effective surgical procedure that minimizes the risk of damage to contiguous vital structures. CDA

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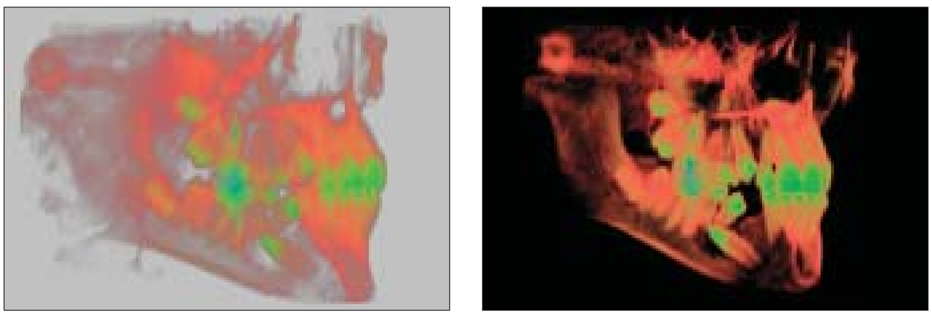

Figure 8. Volume rendered image of the impacted mandibular cuspids.

Figure 9. Orthodontic appliances.

Figure 10. Alignment of the cuspid.

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Newtom QR-DVT 9000 Imaging Used to Confirm a Clinical Diagnosis of Iatrogenic Mandibular Nerve Paresthesia

Michael Erickson, DDS; Joseph M. Caruso, DDS, MS; and Leroy Leggitt, DDS, MS

Abstract

This article describes conventional orthodontic treatment of an adult patient leading to lower lip paresthesia. The paresthesia subsided when the cross elastics to correct the patient's single molar crossbite were removed. It was determined with Digital Volumetric Tomography that the inferior alveolar nerve was located lingual to the lower second molar root and was impinged upon with the tipping force of the cross elastic. Treatment to resolve the crossbite without further paresthesia is discussed.

Loss of sensation in the lower lip is an occasional occurrence in a general dentist's office when anesthetic is being used and is seen as frequently as 60-70 percent of the time after orthognathic surgery. However, during conventional orthodontic treatment it is extremely rare.[1,2] Numbness of the lower lip has been reported to be the first sign of a tumor impinging upon the inferior alveolar nerve.[3] Multiple myeloma, Burkitt's lymphoma, Central squamous cell carcinoma, and odontomas have all been reported to cause paresthesia.[4,5,6] Many dental problems have been reported to cause lower lip paresthesia as well.

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Periapical inflammation, large restorations, endodontic treatment, and a non-vital tooth have all been reported in the literature to induce paresthesia.[7,8,9,10] Because of the numerous etiologies reported with similar symptom, it is imperative a thorough investigation be given when any complaint of facial paresthesia is given.

Figure 1. Patient photograph. Patient has a Class II molar relationship due to absent maxillary canines and a buccal crossbite of her right second molars.

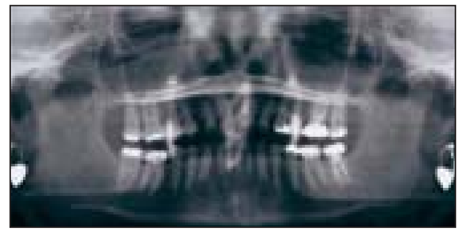

Figure 2. A Panorex revealing no significant information about root/nerve proximity.

Case History

A 57-year-old Hispanic female came to a Graduate Orthodontic clinic with a chief complaint that her upper incisors were flared and there were spaces developing between her teeth. She had orthodontic treatment 15 years prior and had her maxillary canines removed to resolve her protrusion. She presented with a Class II molar relationship due to the absent maxillary canines and a buccal crossbite of her right second molars (**Figure 1**). Pocket depths were all between 2-3mm and mobility did not exceed Class I. The patient had a strong brachyfacial pattern.

The lower first molars were banded and lower 5-5 were bonded with orthodontic brackets. A lingual button was bonded to the lingual of her lower right second molar and a button was bonded to the buccal of her upper right second molar. Elastics were given to the patient to wear 24 hours a day until the crossbite corrected (5/16 4 ounce). A utility arch with ideal buccal segments was placed in order to intrude lower incisors. No appliances were placed on the upper arch except the button on the buccal of the upper right second molar.

She was seen one month later and the crown of her lower right second molar had become noticeably more upright but had not moved buccally. The mobility had become Class I. It appeared that her strong musculature was keeping the second molars locked in crossbite while the root of the lower right second molar was moving lingually.

She wore the cross elastics for two more weeks and at that time came into the clinic because the lingual button had come off. She complained that the day before her lower right lip had gone numb. Using a wisp of cotton and an explorer, the zone of paresthesia was identified as all of the lower lip anterior to the second molar to the midline with the exception of the vermilion.

Observation of the panorex and periapical films revealed no significant information about root/nerve proximity (**Figure 2**). At that time, a scan was taken of the patient on the Newtom QR-DVT 9000. From this scan, it was evident that the inferior alveolar nerve ran lingual to the lower right second molar and that the root apex was penetrating the neurovascular canal (**Figures 3, 4**). The patient was then instructed to discontinue elastics. It was determined that the lower right second molar must be moved bodily and the occlusion must be unlocked to do so.

The patient returned seven days later (eight days since paresthesia started), and reported that the paresthesia was still present. At that time, a maxillary bite plate with relief above the lower right second molar was delivered. A 16x22 archwire was placed that had a horizontal coil distal to the lower right canine and an arm which bypassed the lower right first and second premolars and the first molar and engaged the lower right second molar. This arm was activated with 40 degree of buccal root torque and an occlusal buccal force vector (**Figure 5**). Two weeks following the delivery of these mechanics, the paresthesia subsided and the patient has normal sensation. However, her right second molars were still in crossbite.

Discussion

There are four previously reported cases of iatrogenic lower lip paresthesia caused by orthodontic treatment.[11,12,13] In each of these cases the paresthesia was temporary. It is intuitive that paresthesia resulting from tooth movement would be caused by impingement of the adjacent neurovascular structure. However only recently has dental imaging been able to provide a definitive view of how interosseous structures such as nerves and root apices are related. For example, the previous case reports on orthodontical-

Figure 3.

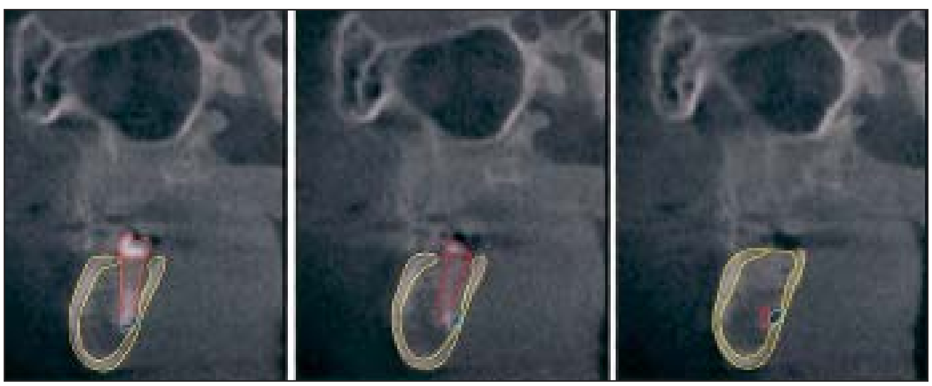

Figure 4.

Figures 3 and 4. Scan done with the Newtom QR-DVT 9000 showing that the inferior alveolar nerve runs lingual to the lower right second molar and that the root apex is penetrating the neurovascular canal.

Figure 5. Patient photograph. A 16x22 archwire has been placed that has a horizontal coil distal to the lower right canine and an arm that bypasses the lower right first and second premolars and the first molar and engages the lower right second molar.

ly induced paresthesia used panoramic, occlusal and periapical radiographs, to determine if the mandibular canal was buccal or lingual to the molar roots. While these investigators attempted to radiographically determine the location of the mandibular canal, they could only assume that the root had actually impinged upon the nerve. With the Newtom QR DVT 9000, we made the constructed cuts through the distal root and could see that the root apex had penetrated the neurovascular canal. CDA

Conclusion

This case illustrates the value of Digital Volumetric Tomography in analyzing the relationships of bone, root apex, and neurovascular canal in cases of iatrogenic mandibular nerve paresthesia.

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Cone Beam Volume Tomography: An Imaging Option for Diagnosis of Complex Mandibular Third Molar Anatomical Relationships

Robert A. Danforth, DDS; Jerry Peck, DRT; and Paul Hall, DDS

Abstract

Complex impacted third molars present potential treatment complications and possible patient morbidity. Objectives of diagnostic imaging are to facilitate diagnosis, decision making, and enhance treatment outcomes. As cases become more complex, advanced multiplane imaging methods allowing for a 3-D view are more likely to meet these objectives than traditional 2-D radiography. Until recently, advanced imaging options were somewhat limited to standard film tomography or medical CT, but development of cone beam volume tomography (CBVT) multiplane 3-D imaging systems specifically for dental use now provides an alternative imaging option. Two cases were utilized to compare the role of CBVT to these other imaging options and to illustrate how multiplane visualization can assist the pretreatment evaluation and decision-making process for complex impacted mandibular third molar cases.

The potential treatment complications and resultant patient morbidity associated with complex impacted "wisdom teeth" are well known. This reality was recently reiterated by a dental liability carrier, which indicated that claims for extractions rate highest in severity and frequency. When emphasizing prevention they indicated that recognizing the difficulty of the proposed extraction is paramount and one of the most important steps is to obtain appropriate radiographs.[1] What are appropriate radiographs or in current terms is appropriate imaging for impacted molars?

The intent of radiographic imaging is to provide an intraosseous view of related structures. Important for assessing

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the treatment complexity, prior to extracting impacted third molars, is its location and position to other structures such as the mandibular canal, adjacent teeth, sinus walls, and cortical borders. In addition, the assessment determines the presence or absence of pathologic conditions and can be beneficial for predicting treatment outcomes.[2] Failure to adequately determine these relationships leaves both the dental surgeon and the patient uninformed of the associated risks, a situation which is well documented by a variety of undesirable treatment outcomes such as nerve damage, bleeding, sinus perforations, and jaw/tooth fractures.

Therefore, proper interpretation of acquired images is essential for treatment success. Unfortunately, interpretation of complex 3-D anatomical relationships is sometimes difficult due to inherent limitations associated with 2-D conventional imaging systems. Valmaseda-Castellon and associates[3] studied the correlation between interpretation of panoramic radiographs and treatment outcomes of 1,117 mandibular third molar post-extraction cases. They found that inferior alveolar nerve damage increased with patient age, deflection of the molar roots when approaching the mandibular canal, proximity of root apices to the mandibular canal, and the need to perform a distal ostectomy. Their assessment criteria are similar to those described by several other current studies.[4-6] While such criteria can be useful to the treating surgeon, actual pretreatment visualization is still lacking.

Tomography is the imaging method use to overcome the limitations of 2-D interpretation. It can be simple film tomography, which provides images made at right angles to one another or complex as with computed tomography (CT) scanners. Although better than the traditional intraoral/panoramic 2-D view, the simple methods still have some inherent film imaging problems such as blurring, appropriate exposure techniques, imprecise site location, varying magnification and image data is limited to the film. This is adequate for routine cases but limiting for the complex cases where the potential for volume analysis and patient modeling could enhance the diagnostic process. Use of CT overcomes these limitations. The computer-generated image better portrays 3-D anatomical truth and as a result, spatial relationships of anatomical structures can be measured, tissue densities evaluated, and image models made. Because of this, CT has become increasing more common for dental imaging.

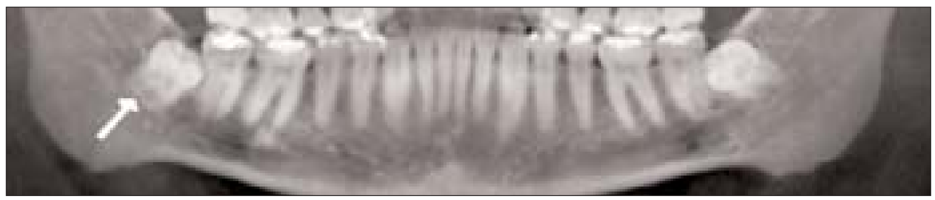

Figure 1a. Mandibular panoramic reconstructed (12 mm thick) from volume imaging. Right third molar is area of interest. Arrow shows superimposed image of nerve canal upon the root apices.

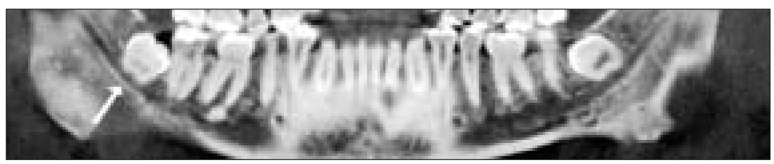

Figure 1b. Similar mandibular reconstruction as 1A, but image thickness is only 1 mm. Nerve canal outline is more pronounced and roots seem to have disappeared (arrow).

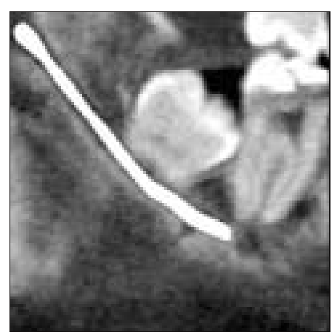

Figure 1c. Enlargement of right third molar ROI. Nerve canal highlighted white.

Despite these advantages, there have been some drawbacks to CT use in dentistry such as access to medical imaging centers, examination costs, and radiation dose to the patient. Because of these limitations and drawbacks, a technology “gap” exists between these tomography options. Recently, several new 3-D imaging systems using cone beam volume tomography (CBVT) have been developed specifically for dental use. These systems appear to bridge the technology gap providing alternatives to film radiography and CT. More common in the European and Asian mar-

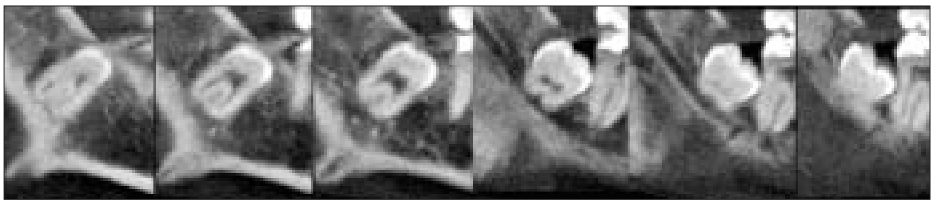

Figure 1d. Sagittal (distal-mesial) views of right molar ROI. A composite of noncontiguous selected 1 mm imaging layers moving from most buccal (left image) to most lingual (right image). Nerve canal observation begins as root apices start to disappear (short arrow) and is most delineated in next more lingual image (large arrow).

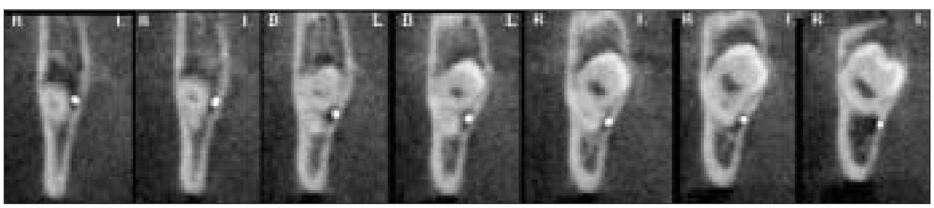

Figure 1e. Coronal/cross-sectional (buccal-lingual) views of right molar ROI. A composite of noncontiguous selected 1 mm layers moving from most posterior (left image) to most anterior (right image). Nerve canal (white dots) show canal lingual to root apices, but in mid-region the roots curve to the lingual somewhat enveloping the passing canal.

kets, some are now commercially available in the U.S. and others will be soon. Purchase price ranges from $200,000 to $300,000. Although a few have been installed in private dental offices, most are in dental imaging centers or dental schools. Current use suggests CBVT imaging will play a major role in the future of dental imaging.

The intent of the article is to present two case reports as examples of how one of these devices (Newtom 9000, Aperio Services Inc., Sarasota, Fla.) is currently being used in the diagnosis and treatment planning of impacted third molars.

CBVT Examination Procedures

Patients were referred to the dental imaging center for the scanning procedure. The Newtom 9000 performs a 75-second scan to obtain patient image data for a maxillofacial volume extending approximately from the lower orbit to just below the inferior border of the mandible. Images are reconstructed without magnification, size or shape distortion from a full maxillofacial volume scan made with a 0.3 mm voxel size and eight-bit grayscale resolution. Once the raw data is reconstructed, patient 3-D multiplane images or image models can be viewed and image data is transferred to the referring dental office. Patient effective dose per examination has been measured to be 50 μSv[7] similar to that for a standard complete-mouth intraoral periapical survey.[8]

Illustration Case I

The patient was a 24-year-old man who went to the oral surgeon for possible removal of his unerupted right mandibular third molar. He had been suffering with chronic pericoronitis for the past year. At the consultation appointment, a panoramic radiograph was made and it showed the mandibular nerve to disappear at the apical one-third of the impacted molar. This raised an immediate concern that the nerve canal may be encased within the root apices presenting a significant risk for nerve damage during the extraction of the tooth. The decision to extract the tooth was postponed until the patient could receive a 3-D volume imaging examination.

Image Analysis of the Impacted Right Mandibular Third Molar

Concern focused upon whether or not the nerve canal passed through the root bifurcation. **Figure 1a**, a 12 mm-wide/thick reconstructed mandible panoramic image, confirmed (white arrow) the findings of the initial panoramic radiograph. The effect of using a narrower tomographic image can be seen with **Figure 1b**. This image is 1 mm in width and while delineation of the nerve canal had become more pronounced, the roots seem to have disappeared or become shorter. Since the anatomical volume of the molar and nerve are much greater than 1mm, the entire region of interest (ROI) required evaluation of multiple image layers/slices in various planes to construct an accurate 3-D view for determining the actual relationship of the nerve canal to the root apices. **Figure 1c** is an enlargement of this area, showing the use of the machine's software program paint tool to mark areas of interest with color identification. In this case, the nerve canal had been color marked (red original, white for this article) and this marker is then carried to any other image reconstruction so that anatomical relationship can be accurately determined regardless of the plane of viewing.

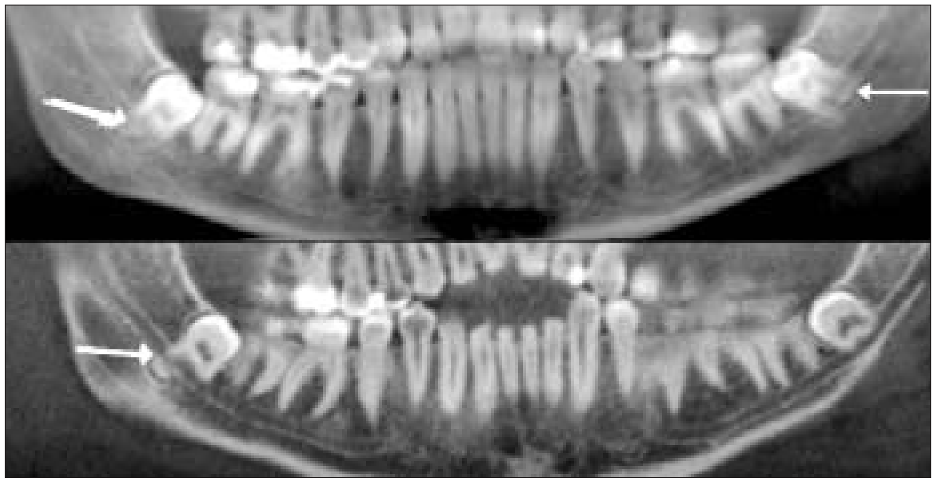

Figure 2a. Mandibular panoramic reconstructed from volume imaging (image layer top-12 mm thick, lower, 1 mm). Right third molar is selected ROI. Left arrows show superimposed image of nerve canal upon the root apices and distal curve of root.

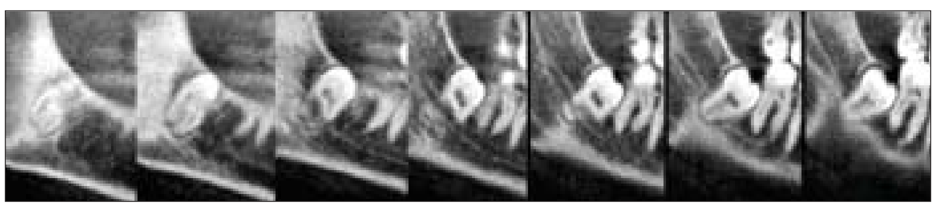

Figure 2b. Sagittal (distal-mesial) views of right molar ROI. A composite of contiguous selected 1 mm imaging layers moving from most buccal (left image) to most lingual (far right). Nerve canal seen (arrow) show a slightly altered pathway and appears partially encased by root apices.

3-D Reconstruction of ROI

A series of 1 mm thick image layers were made by the computer in a "step-by-step" approach to reconstruct the ROI into a 3-D view. The images are generally made at 90 degrees to each other. **Figure 1d** is a composite example of multiple sagittal (distal–mesial) plane images which displayed the anatomical changes that occurred as viewing moved from the buccal surface (left images) to the lingual (right images). Following the images from left to right, showed the root apices appeared first and started to disappear as the nerve canal came into view suggesting that the roots apices were buccal to the canal. The best view of the nerve canal (large arrow) lacked the apical half of the molar supportive of the previous image interpretation. While these views were similar to the panoramic in **Figure 1a**, the ability to see individual incremental layers resulted in a completely different interpretation.

This interpretation was support by the cross-sectional/coronal images of **Figure 1e**. These images were made at 90 degrees to the previous sagittal views and were similar to what is done for dental implant imaging of the mandible. In this case, the diagnostician started the review from the posterior/distal segments (left image) and followed the nerve canal (white dot) anterior as it passed the molar to the final image (most right). It was observed that the nerve canal remained lingual to the molar in all images but at the mid-range, it appeared that the molar roots curved to the lingual and partially enveloped the canal. Such a visual finding was not available with any form of panoramic imaging. In this case, beside the 90-degree cross- sectional/coronal images being supportive to the imaging seen in **Figure 1d**, it was also additive because the lingual hook of the root apices was clearly seen.

Surgical Observations

After reviewing the images, the decision was made to proceed with the extraction to resolve the chronic pericoronitis problem. A cautious conventional surgical protocol was used enabling the tooth to be successfully removed without damaging the mandibular nerve canal and as a result, the patient did not sustain any neurological defect. Upon inspection of the extraction site, the nerve canal was located exactly as it was shown by the volume scan examination.

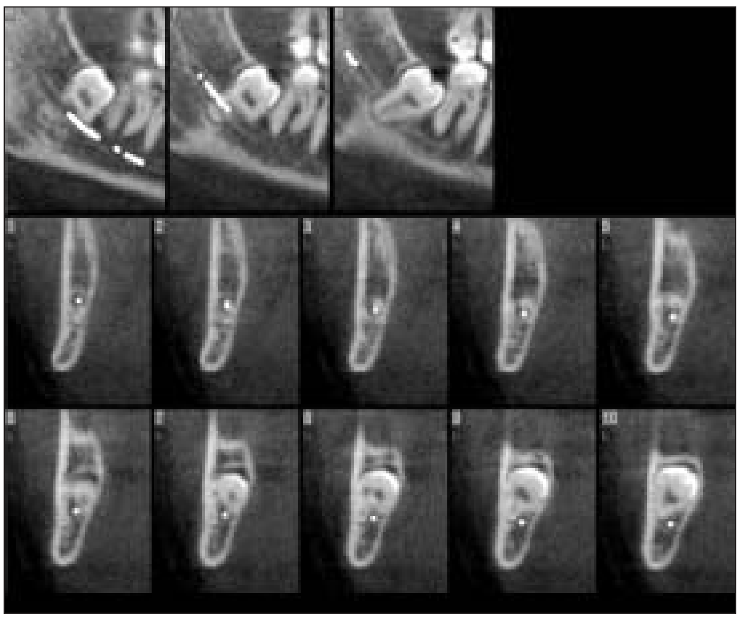

Figure 2c. Selected sagittal views with paint tool (top) and contiguous 1 mm coronal/cross-sectional views (frames 1-10). Nerve canal (white dot) appears partially encased by root apices (frames 3-6).

Illustration Case 2

A 23-year-old female patient was referred to the oral surgeon for extraction of all four third molars. Her chief complaint was about pressure from the maxillary molars, which she claimed occasionally gave her headaches. Although the mandibular third molars were asymptomatic, she wanted all of the thirds molars removed since she was relocating and dental benefits might not be available. A panoramic radiograph made at the consultation appointment showed the mandibular nerve passing through the middle of the third molar roots, raising concern that the nerve was encased with the roots posing significant risk for damage if the teeth were extracted. Although there was no immediate plan for removing these teeth, the patient agreed to a volume imaging scan to better understand the nerve and root relationship for future reference in case the teeth became symptomatic.

Image Analysis of the Impacted Right Mandibular Third Molar

The patient was referred for a 3-D volume imaging examination when the initial panoramic radiograph indicated that the mandibular nerve canal might go through the root bifurcation of both the right and left impacted mandibular third molars. **Figure 2a** (top) was the 12 mm reconstructed mandible panoramic image which confirmed (white arrows) the findings of the initial panoramic radiograph. The lower 1 mm image further defined the problem when it can be seen that the nerve canal appeared surrounded by the right molar root apices (arrow, lower). The right molar was selected as the ROI for 3-D evaluation.

3-D Reconstruction of ROI

Selected contiguous 1mm sagittal views can be seen in **Figure 2b**. The most buccal image (far left) showed that the apical portion of the root came into view first. As viewing moved more lingual to the right, the complex relationship of the nerve canal and the root apices could be seen in image frames 3-5. The root appeared curved and there was deviation of the nerve canal in frame 3. In frame 4, the canal was better delineated, but still had a superior portion covered by the root. Frame 5 best showed the apparent “grip” (arrow) the root had upon the nerve canal as it passed through the molar. The last two frames indicated that most of the coronal portion of the molar was lingual to the nerve canal. **Figure 2c** was a composite of selected sagittal views, which showed the color identification marker of the nerve canal and a series of 1 mm contiguous cross-sectional/coronal views (images 1-10). The first image frame was the most posterior and showed only the tips of the distally inclined root. As the view moved more anterior toward frame 10, the outline of the root apices and position of the nerve canal became more complex. This was best seen with frames 3-6 where the nerve canal seemed almost encased by the root apices. Finally, as the canal exits past the molar (frames 7-10), it can be seen inferior and somewhat centrally positioned to the coronal portion of the tooth.

Scan Consultation

The volume scan validated the panoramic concerns that indeed the nerve was encased with the roots of the third molars. The patient appreciated having done the scan imaging and made an informed decision to postpone extraction of the mandibular molars.

Discussion

CBVT is an emerging technology for dentistry that offers alternative imaging options between standard film radiography and tomography, and medical CT. The case examples illustrate how computer-assisted imaging provided multiplane viewing and tracking of the mandibular canal through various image planes. Such imaging capabilities not possible with standard film radiography or tomography are available with CT, but at a higher patient dose and examination fees. The patient effective dose from a CT dental implant scan measured specifically for the mandible is most comparable to that for a full volume Newtom 9000 scan. Several studies report the mandibular effective dose for dental implant CT to range from 123 µSv to 528 µSv.[9-12] This is several times greater than the 50 µSv[7] reported for the Newtom 9000 full volume scan. Fees for a CBVT examination may vary from $250 to $350. Generally, this would be slightly higher than for a film tomography examination (estimated range $150 to $250) and less than CT (about $300 to $800).

The Newtom 9000 CBVT imaging proved beneficial for both pretreatment evaluation and surgical risk assessment. Based upon the imaging, the first patient made an informed decision to proceed with the surgery, which was successful and verified the interpretation of the images. The second patient postponed extraction determining the surgical risk was greater than the benefit of removing the asymptomatic impacted molar.

Conclusion

CBVT is a an emerging technology that provides computer-assisted multiplane imaging for complex mandibular third molar surgical cases and is a lower dose alternative option to medical CT. **CDA**

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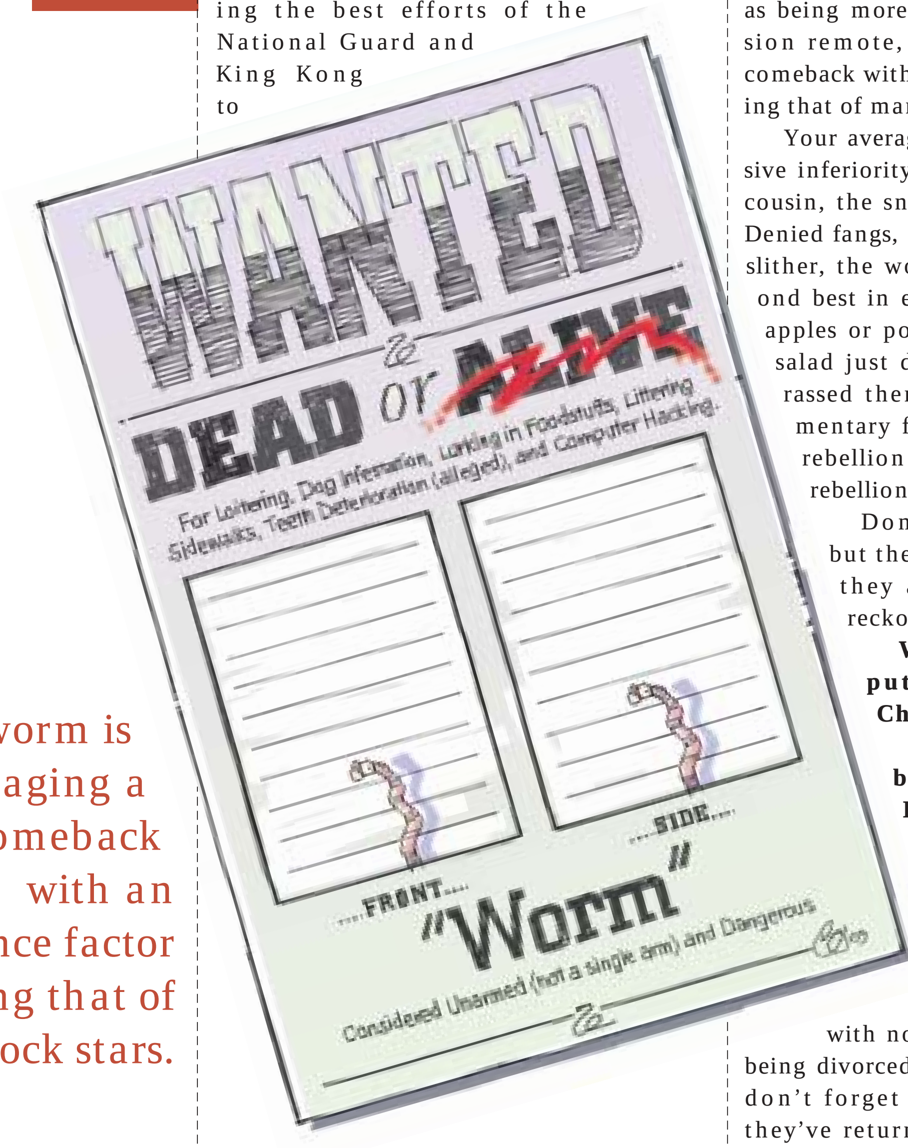
Robert E. Horseman, DDS

Nematodes Worm Their Way Back to the Top

Until recently, ants had the dubious distinction of being society's most annoying life form next to restaurant cell phone users. Ants spoiled picnics; they got in your pants. Once they got a taste of radioactivity, they ran amok in sci-fi B movies defying the best efforts of the National Guard and King Kong to wrest Faye Wray from their lustful clutches. Every ant looked like every other ant and we hated them all.



The worm is staging a big comeback with an annoyance factor exceeding that of many rock stars.

Meet the new champ, that elongated, usually naked, soft-bodied animal, the worm. Universally held beneath contempt as being more useless than a Braille television remote, the worm is staging a big comeback with an annoyance factor exceeding that of many rock stars.

Your average worm has long felt a massive inferiority complex heightened by his cousin, the snake and not without reason. Denied fangs, poison sacs and the ability to slither, the worm came off a pathetic second best in every department. Lurking in apples or popping up unexpectedly in a salad just didn't cut it. Early birds harassed them. Likened in an uncomplimentary fashion to wimpy husbands, rebellion was inevitable. And what a rebellion it has been!

Don't ask us how they did it, but the headlines make it clear that they are back and a force to be reckoned with.

Worm shuts down GM computers! Thirty thousand Chevrolets die!

Northeastern grid disabled by computer worm virus. Energizer bunny linked to conspiracy!

We should have seen this coming. When your dog got worms, what was the solution? He was dewormed, of course, and with no more fanfare than you'd get being divorced by Elizabeth Taylor. Worms don't forget slights like that and now they've returned to wreak vengeance on

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their tormentors. The worst of it is that we, as dentists, are partly responsible for this present day crisis.

Once upon a time, according to Dr. Malvin Ring, dentistry's authoritative link to the past, worms got a lot of respect, especially among the dental profession. To understand this, reflect for a moment on the oral health of a 1600s citizen. "Hollow teeth" were endemic, i.e., teeth that had deteriorated to the point of resembling the Coliseum in structure. Packed with food debris, it became necessary to continually suck on these carious teeth. A gathering of hollow-toothed people would sound like a bunch of today's teenagers in a malt shop all inhaling the last of their Diet Pepsis through straws. Toothache, of course, was common and was ascribed to the gnawing action of "tooth worms."

Even into the late Renaissance period, this belief in worms as the causative agent of dental caries was firmly held. Many reputable and prominent authorities of the day supported the theory in spite of the worms' vigorous denial that they had anything to with the problem. "OK," they admitted, "we may have messed up some produce and littered the sidewalks after a rain, sure, but living in a hollow tooth? Get real!"

Then Bill Gates and Al Gore invented the computer and, like Arnold Schwartzenegger, the worms are back.

Even Pierre Fauchard was reluctant to deny the possibility of the tooth worm. Even if there are worms, he cautions, they had to arrive via corrupted foodstuffs, not by Immaculate Conception.

So to settle the matter, a researcher by the name of Anton van Leeuwenhoek of Delft, Holland was called in. He is credited with being the father of modern microscopy and a master of scientific deduction. Anton came up with this idea: Everybody likes cheese. Flies like cheese. Flies lay eggs in cheese. People eat cheese, tucking away unswallowed bits in their hollow teeth. Eggs hatch into worms and somewhere along the line turn back into flies again. This is called "The Circle of Life" he said, failing to copyright the phrase, thus losing a fortune to Elton John years later.

The years went by without much happening except a few wars and famines until finally Louis Pasteur proved that a worm causing a toothache was the dumbest idea since the Flat Earth Theory. The worms' 15 decades of notoriety had passed. Then Bill Gates and Al Gore invented the computer and, like Arnold Schwartzenegger, the worms are back.

Now would seem to be the time to lure them out of the hard drives with all that surplus cheese held in government warehouses. **CDA**