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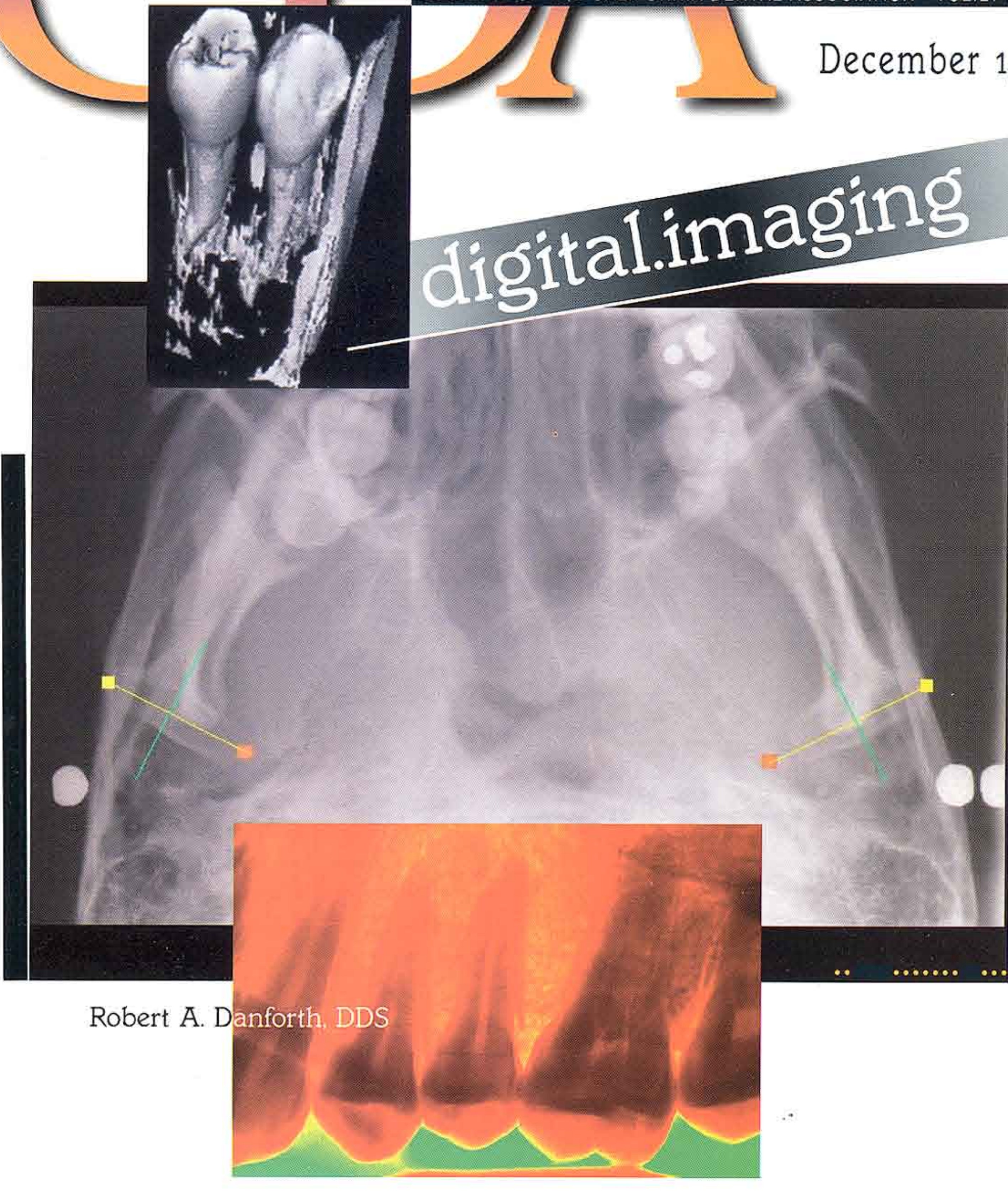

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OF THE CALIFORNIA DENTAL ASSOCIATION
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DEPARTMENTS

FEATURES

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Analyzing the Subjectivity of 'Need'

Jack F. Conley, DDS

The American Dental Association House of Delegates had not approved recognition of a new dental specialty since endodontics became the eighth specialty in 1963. However, interest and activity in this area have not been lacking. In the past 13 years, the ADA Council on Dental Education has reviewed 16 applications for specialty recognition. Further, from 1994 through 1997, the council recommended five of seven applications it had received. Yet, from 1986 through 1997, the ADA House rejected all eight applications forwarded.

As a longtime observer of the ADA House actions, it is easy to understand the frustration that may have been felt by many in the organizations that have been denied recognition. For some organizations, that unhappy reality has been experienced two or three times. Despite a detailed review by the Council on Dental Education and its Committee G, and subsequent recommendations for approval by ADA Boards of Trustees in past years, the House actions on specialty recognition have often seemed to be swayed by subjective or emotional considerations.

In 1999, the process followed by the ADA Board in making its recommendations and a similar process employed at the ADA House seemed to suggest that the decisions reached by the House this year would be more objective than prior decisions had been. The process was straightforward. Each applicant needed to show compliance with six requirements. The ADA Board and House were each asked to base their assessments and votes for approval or denial on whether the organizations had met (or successfully addressed in their applications) each of the six requirements for dental specialty recognition as specified in ADA's "Requirements for Recognition of Dental Specialties and National Certifying Boards for Dental Specialists." At the House, failure to receive approval on any one of the six requirements would automatically deny specialty recognition to the applicant.

The requirements are:

1. In order for an area to be recognized as a specialty, it must be represented by a sponsoring organization: (a) whose membership is reflective of the special area of dental practice; and (b) that demonstrates the ability to establish a certifying board.

2. A specialty must be a distinct and well-defined field which requires unique knowledge and skills beyond those commonly possessed by dental school graduates as defined by the predoctoral accreditation standards.

3. The scope of the specialty: (a) is separate and distinct from any recognized specialty or combinations of specialties; and (b) cannot be accommodated through minimal modifications of a recognized specialty or combination of recognized specialties.

4. In order to be recognized as a specialty, substantial public need and demand for services, which are not adequately met by general practitioners or dental specialists, must be documented.

5. A specialty must directly benefit some aspect of clinical patient care.

6. Formal advanced education programs of at least two years beyond the predoctoral curriculum as defined by the Commission on Dental Accreditation's Standards for Advanced Specialty Education Programs must exist to provide the special knowledge and skills required

for the practice of the specialty.

Three applications were forwarded by the Council on Dental Education and Licensure via the ADA Board for consideration by the 1999 ADA House. They were, in order of their consideration, from the American Academy of Oral and Maxillofacial Radiology, the American Society of Dental Anesthesiologists, and the American Academy of Oral Medicine. The applications for radiology and anesthesia were approved by the council, but only the application from radiology was endorsed by the ADA Board.

The House voting process, while closely linked to the requirements, nonetheless showed that one of the requirements is still vulnerable to subjective interpretation by those called upon to assess compliance, whether the assessments are at the council, Board, reference committee, or delegate level. In the House vote on radiology, all requirements except one were approved by a substantial majority of the delegates. However, requirement 4 regarding need was barely approved by a scant percentage. Nonetheless, oral and maxillofacial radiology was approved as a dental specialty, the first such recognition in 36 years.

The votes on the anesthesiology application were favorable on five of the six requirements, although the percentage of votes for approval of each was less than in the case of radiology. The vote on requirement 4 -- need -- fell short of the simple majority required for approval. It does seem to this observer that the manner of documentation of definition of need as it pertains to this requirement must be clarified. The current requirement still allows too much subjective interpretation. The fact that too many individuals on the Board and the Education Reference Committee to the House, as well as the delegates at large, were divided in their analysis of the requirement, provides strong testimony to the need for further clarification of this standard.

This process must remove all possibility of emotion or subjective opinion on major decisions influencing the future directions of organized dentistry and its components. It was clear that the process has been upgraded from what it has been in the past. However, it can still benefit from refinement before the next application is reviewed.

In the meantime, congratulations are in order for the American Academy of Oral and Maxillofacial Radiology. Satisfying the current requirement of need, even if by the breadth of a fine hair, qualifies as a significant achievement.

Ben Franklin Would Be Proud

By David G. Jones

Dentists long ago could hop into their electric automobiles -- at the turn of the last century they were more popular than gasoline-powered models -- drive to their practices, and restore teeth with an electric-powered handpiece. A dentist now can do much the same, but the electric handpiece, just like the electric car, has undergone an almost complete metamorphosis in the century since 1899.

Today's electric handpiece, like its counterpart in the automotive world, is a far cry from its ancestor, both in form and function. While its use in Europe is widespread, it is not yet a real competitor to the air turbine handpiece in the United States. Although the air turbine handpiece has represented the state of the art since the mid-1950s, the electric handpiece is slowly finding its way back into American dental practices. Better technology is providing the key.

"We were never able to go back to electric handpieces because it wasn't thought they could keep the revolutions up and at the same time provide a smooth-running unit," says Douglas H. Kazen, BSPh, MS, PhD, president of Aseptico, Inc., in Kirkland, Wash., a dental equipment manufacturer. "Now we can do these things because bearing technology has moved so far ahead that we can provide systems that are steam autoclavable, and we can give doctors predictable speed and a reduction in aerosolizing."

While attending dental school at the University of California, San Francisco, Robert L. Miller, DDS, now practicing in Pleasant Hill, worked as an aerobiologist, studying aerosolization. He says he has found that the electric handpiece is superior to air-driven units in reducing aerosols because of a slower operating speed and no need for an air and water spray.

"With air-powered handpieces you put up an extraordinary amount of aerosols," Miller says. "When I studied the use of the electric handpiece in a bloody field, I could find no significant amount of blood being aerosolized."

Brian G. Shearer, PhD, director of the American Dental Association's Council on Scientific Affairs Department of Information and Policy, says that even though the electric units may reduce aerosols, there is no scientific proof that they also reduce infection in the dental office.

"As yet we really have no scientific evidence suggesting that aerosols result in infection," Shearer says. "If these units reduce aerosolization, that's a good thing. But the point is that if the standard handpiece is used properly with infection control techniques, we have no documented scientific evidence that they result in occupational infection."

Miller, a general dentist, says that there is another advantage to the electric handpiece's slower speed.

"It can be set for a very slow speed -- around 300 rpm -- that is useful for endodontic files," Miller says. "It allows you to electronically tune whatever speed you want to use. You don't have to worry about overspeeding it."

Alan L. Felsenfeld, DDS, CDA's new chair of the Council on Dental Research and Developments, says that for the vast majority of practitioners, the air-driven turbine is the standard now and into the future for preparation of teeth for restorations.

"But for supplemental use in endodontics, oral and periodontal surgery, and implants, this is an excellent instrument to add to our offices," he says.

Felsenfeld, an oral and maxillofacial surgeon, says the delicate preparation of a tooth restoration can't easily be done with lower-speed electric drills, but advantages exist nonetheless.

"In oral surgery, for example, electric handpieces offer high torque, and this is a tremendous advantage," he says. "It is reasonably speedy for removing bone, and the handpiece, including the cord, can be sterilized. More importantly, electric handpieces don't blow air into the wound with the potential for introducing harm to the patient."

An assessment by Ian Van Zyl, DDS, BDS, MS, an assistant professor of fixed prosthodontics on the faculty of the University of the Pacific School of Dentistry, differs from Felsenfeld's.

"We performed a double blind study using the electric handpiece with dental students nearing the end of their first year who were already highly skilled with the air turbine," Van Zyl says. "This was the first time they had picked up the electric motor, and cavity preparations using both systems showed no statistically significant difference."

One drawback of electric handpieces is the cost, which is several times higher than that of an air-driven unit.

"There is an initially higher cost when purchasing an electric handpiece, but if you consider its longevity and reduced maintenance needs, the extra cost can be amortized over a few years," Felsenfeld says.

Miller says another concern is that some of the electric units heat up if used for long, sustained periods.

"I found one designed for oral surgery that was useful only for short-time use," he says. "It heats up too much because it doesn't have an internal cooling system."

Kazen admits that introducing the new electric handpiece technology to general dentistry will be a long-term process.

"Most dentists are not quite ready to

Trading Spit for Stick

A recently released saliva-based genetic test for periodontal disease is expected to replace the blood-based test currently used by some in the periodontics community.

The new test, from Interleukin Genetics, Inc., is designed to be quick, reliable and convenient so dental practices may incorporate the testing more readily. The new test was introduced in September.

Dr. Ken Kornman, Interleukin's president and chief scientific officer, says, "Based on technical innovations, it is now possible to use saliva instead of blood as a reliable source of DNA. Feedback from dentists about this advance has been positive, since saliva collection will reduce the time and potential patient discomfort associated with finger-stick blood collection."

re-equip their operatories," Kazen says. "If a dentist switches to electric, he will immediately antiquate expensive air-driven equipment. So it will happen from the ground up, little by little."

Talking the Talk

By Dell Richards

Whether they want to or not, many dental professionals are called upon to speak to some sort of public group at some point during their careers. Public speaking and presentations can be a very effective way of attracting new patients.

Whatever the occasion, knowing how makes public speaking easier. Here are some observations that should help:

- Most speakers start with a humorous remark to put the audience at ease. Unless the topic doesn't lend itself to humor, wit can make a speech more enjoyable for everyone. A speaker should try to work in a light remark. If humor isn't a comfortable style for a speaker, he or she should open by saying how pleased he or she is to be there. Making the audience feel appreciated also will get their attention fast.
- Notes should consist of keywords in big bold letters that can be read from a distance. A speech should not be written out, memorized and read. The best speeches seem extemporaneous, even though they may have been rehearsed a hundred times. Using keywords for general points can create a spontaneous feel.
- It is harder for people to remember information that has been heard rather than read. That's why TV advertising has the name, logo and slogan as well as action and dialogue. A speaker should open a talk by telling the audience what he or she is going to say. Then, he or she should discuss the subject, and close by reiterating key points.
- For that same reason, a speaker shouldn't make more than three major points. Sub-points and anecdotes can be used to flesh out a general theme, but the main points should be kept to a minimum.
- Pace is important. Some speakers should tap their foot every second and speak a word with each tap. For higher energy, the pace can be increased. But a speaker should practice speaking slowly. He or she will undoubtedly speak faster when giving the presentation.
- A speaker should practice looking around the room while speaking. He or she should move his or her head slowly to make eye contact with individuals in the room. If nervousness makes it difficult to look at anyone directly, the speaker should look at people's foreheads. They will never know the difference.
- Broad gestures can be effective, but hand-flapping or clicking coins in the pocket is distracting, if not downright annoying.
- A speaker should wear a dark blue suit and/or a light blue shirt. "IBM blue" -- the blue that most companies use -- has the most credibility of any color. People will be inclined to believe the speaker because blue says "Trust me. I know what I'm talking about."
- Practice makes perfect. A speaker should practice alone, without a mirror at first. He or she should then work up to a mirror or a friend. Those with a camcorder should videotape themselves again and again. Those who are really serious about becoming a good speaker should join Toastmasters International. Most cities have a chapter listed in the phone book.
- When practicing, one shouldn't be hard on oneself. A speaker is creating a special persona -- which is never easy. A beginning speaker may feel like a fool, or even an imposter, at first, but should keep at it. People learn by experiment, trial and error, and doing the same thing again and again until they get it right.
- Smiling is a key factor. Surveys show that 93 percent of what audiences remember is nonverbal. The voice and the smile combined are the second most important factors after the information itself.
- Publicity can help. A speaker should send a notice to the local paper announcing the speech to generate interest and publicity.

Learning speaking skills is like breaking in a new pair of shoes -- they're never really comfortable until they've been worn a while.

Dell Richards is owner of Dell Richards Publicity in Sacramento.

Professionals Should Help Boost Health Awareness

Patients referred to periodontists often have no idea they have undiagnosed and uncontrolled health problems, some of which can affect their dental treatment, according to a study published in the October 1999 issue of the Journal of Periodontology.

Dental professionals routinely have patients complete health histories during their initial visit. The study compared self-reported medical histories from 39 consecutive patients with moderate to advanced periodontal disease to laboratory data obtained when patients were then referred to a hospital for urinalysis, complete blood count, and a standard blood chemistry panel.

While no patients in the study reported having diabetes, 15 percent tested positive for the disease. In addition, only 5 percent of participants reported a history of abnormal cholesterol, while 56 percent tested positive for exceptionally high values, putting them at greater risk for strokes and heart attacks.

"These and other underreported conditions found in the study are alarming because it's important for patients to know what diseases they have or are at high risk for so that they can take steps to control the diseases," says the study's lead researcher, Dr. Kelly Thompson. "From a dental practitioner's standpoint, these findings also mean that we may not always be made aware of what we're up against. Undiagnosed and uncontrolled diabetes can have a profound impact on oral health and can greatly affect treatment procedures and outcomes."

The study cites a need for dental professionals to emphasize to patients the importance of routine physical examinations and preventative care. "Our patients who exhibit risk factors could benefit from physician referrals," Thompson says.

Better Communication May Minimize Children Complaints

Most problems between dentists and children can be handled through better communication, according to Greg Johnson, director of professional services for the Illinois State Dental Society, and staff liaison to the ISDS's Peer Review Committee.

In an article in the August 1999 Illinois Dental News, Johnson writes that of the 500 peer review cases handled by the committee each year, about 10 percent involve children. He writes that complaints involving children frequently include three issues: parents who are not allowed into the operatory with their child; "hand-over-mouth" behavior control techniques; and continuing a procedure even after a child indicates the dentist should stop. Johnson says that dentists can frequently eliminate these problems by addressing them ahead of time with the child and parent.

Dentists who prefer not to have parents in the operatory should make that office policy clear to the parent ahead of time. "I think at times if a parent objects to a particular policy, maybe it's best the dentist refer them to a colleague who will allow the parent in," says Dr. Richard Kirchoff, a past president of the Illinois Society of Pediatric Dentists. If the parent is to be allowed, ground rules need to be established, Kirchoff notes. The dentist should make it clear that a parent is to be a "quiet observer," sitting in front of the patient, and perhaps holding a child's hand for comfort.

The "hand-over-mouth" technique of controlling a child patient, while approved by the American Academy of Pediatric Dentistry, doesn't always please parents. For those who do use the hand-over-mouth technique, it should be done in a non-angry, non-aggressive manner, without reducing the airway.

Johnson's article notes many dentists find the hand-over-mouth technique ineffective, noting that if a child's behavior is out of control to the point where the dentist considers using it, it may be best to stop the procedure. According to the article, a parent should be informed prior to its use, and preferably a signed consent form should be obtained from the parent. Johnson notes other methods of control tend to work better, such as voice control.

For children in or near hysterics, another recommended method is the T.O.T.S., or Take Off The Shoe method, based on the theory that four-year-olds don't like to have their shoes taken off. Dentists can promise to replace the shoe if the child cooperates.

As for complaints about dentists continuing treatment after the child indicates he or she wants it stopped, it's important for the dentist to give the child a signal, such as raising a hand, when they want the dentist to stop. The dentist should stop, give more anesthetic, or take other measures to make the child more comfortable. Letting the child and parent know what the procedure involves ahead of time can alleviate problems. Better communication helps all the way around, Johnson notes.

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Good Phone Manners Are Good Business

Proper use of the telephone can be a powerful marketing tool for a dental practice, according to an article by Dr. Robert Ash, BS, CP, ACHE, in the July/August issue of the Journal of Dental Technology.

Since a caller's first impression of a business is frequently over the telephone, the most costly business mistakes are made in the first few seconds. The person answering the phone must be able to sell your image quickly and effectively, Ash writes.

"Statistics show that telephone vocal quality accounts for 70 percent of the first impression you make and the words spoken count for 30 percent. Since the telephone is one of the most used tools in the work of your company, how you and your employees use this tool is very important," Ash writes.

The best time to answer the phone is on the second ring, Ash writes. If a second line rings while you're talking to another person, ask permission to put the caller on hold, then give them time to respond. Never say "hold on," or "hang on." Pick up the second call, explain you're on the other line and you'll call back shortly, and take a brief message. Get back to the first call within 30 to 45 seconds, and thank them for waiting.

Top Tips

- Courtesy is most important.
- Treat every caller as a special person. Give your undivided attention to every call.
- Put a smile on as you answer the telephone. The caller can "hear" you smile.
- Put energy into your voice.
- Identify your office and name.
- Always keep paper and a pens handy for notes.
- Keep food and pens out of your mouth so as not to garble your words.
- Be willing to give out information; don't make the caller drag it out of you.
- Be professional.

CDC Presents More Fluoride Support

Dental treatment costs for low-income children can be twice as high and crisis intervention more frequent in nonfluoridated communities than in those with fluoridated water, according to a Sept. 3, 1999, report from the Centers for Disease Control and Prevention, published in the CDC Morbidity and Mortality Weekly Report.

Findings of the study, which was

conducted in 19 Louisiana parishes (counties), suggest that very young children lacking access to fluoridated water were three times more likely to receive dental treatment in a hospital operating room than children in communities with optimal levels of fluoridated water.

"CDC's data are useful for community decision makers as they consider implementing water fluoridation," says Dr. Kimberly McFarland, vice chair of the ADA Council on Access, Prevention and Interprofessional Relations and chair of the council's National Fluoridation Advisory Committee. "From public health experience across the country, we have always known that fluoridation saves money. These data document that water fluoridation is beneficial especially for low-income populations."

The study reports that more Medicaid-eligible children in nonfluoridated parishes received caries-related dental treatment and operating-room-based care at greater cost than did Medicaid-eligible children in fluoridated parishes. The expected annual reduction in dental treatment costs for at least 39,000 preschoolers in Louisiana, as a result of potential benefits from water fluoridation, would be $1.4 million.

Other studies have found that caries in the primary dentition disproportionately affect children from low-income households, including a study reported in the September 1998 Journal of the American Dental Association.

The authors of the CDC-reported study say they did not measure the length or magnitude of the children's exposure to fluoride and said the findings are subject to other limitations. Lower treatment costs associated with water fluoridation should not be generalized to preschool children from middle and high income families because of their lower prevalence of dental decay, the authors say.

Honors

Jack F. Conley, DDS, editor of the Journal of the California Dental Association, has been named the holder of the Rex Ingraham Chair in Restorative Dentistry at the University of Southern California School of Dentistry.

Donald S. Clem, DDS, a private periodontal practitioner in Fullerton, Calif., received a Special Citation in recognition of his outstanding contribution to the American Academy of Periodontology.

Web Watch: Continuing Dental Education

The following pages have information on continuing education courses provided by the five California dental schools.

http://www.llu.edu/llu/dentistry/cde/cdehomepage.htm

Information from Loma Linda University

http://www.dent.ucla.edu/ce/

Information from the University of California at Los Angeles

http://itsa.ucsf.edu/~dental/sod_center.htm

Information from UC San Francisco

http://www.dental.uop.edu/ (Click on "Dental Professionals")

Information from the University of the Pacific

http://www.usc.edu/hsc/dental/Info/CE/index.html

Information from the University of Southern California

A listing here does not constitute endorsement by the California Dental Association. As is the case with all web sites, content is subject to frequent change.

Digital Oral and Maxillofacial Imaging: A New Image for a New Age in Dentistry

Robert A. Danforth, DDS

AUTHOR

Robert A. Danforth, DDS, is an assistant clinical professor in the Department of Oral and Maxillofacial Imaging at the University of Southern California School of Dentistry.

New Year 2000 is now "virtual reality." It is the dawn of a new age, and people have millennium fever. Likewise, dentistry is at the threshold of a new age. Technological advances of the past decade have already changed many aspects of dental practice, and the future holds many more new and exciting possibilities. The *Journal of the California Dental Association* also shares this excitement and recognizes the unique opportunity in time afforded to this issue to view a vision of the future while still in the shadow of the past. As such, the Journal selected digital imaging radiography as the subject of this vision, deeming it the technology most ready to significantly affect the future practice of dentistry. To develop this issue, I was asked to arrange for the contributing authors and provide some introductory comments.

While the decision for the theme of the Journal was made several months ago, it is of interest that as we were finalizing the issue in October, the American Dental Association elected to recognize oral and maxillofacial radiology as dentistry's newest specialty. Such recognition indicates that dentistry similarly shares the vision of a digital future and has identified a specialty to lead and direct the development of it for the entire profession.

The need for direction for the future is apparent by reviewing the past. Dental imaging, until recently, has only modestly evolved from the early days of Roentgen. It is still primarily film-based and directed toward periapical and bitewing radiography for general dentistry. Granted, other forms of radiographic imaging have been introduced during the past century, but other than panoramic technology, none have made a significant impact upon general practice dentistry. There has been some trickle down effect from medical imaging as advanced technology has produced an awareness of digital imaging and its potential application to dental radiography. This has influenced the development of digital dental imaging during the past decade. When introduced, digital radiography was seen as the key element in achieving the goal of the paperless dental office. Yet, despite availability and considerable media hype associated with digital imaging, as dentistry approaches the next century, the same cautious curiosity is apparent that confronted X-ray imaging at the beginning of the 20th century. Current estimates of digital imaging utilization in the United States are 5 percent to 7 percent of dentists. Why is this, and what will effect a change?

It is the purpose of these articles to highlight various aspects of digital imaging technology for dentistry and to answer the why and what questions. We did not intend to scientifically prove or disprove the validity of digital imaging for dentistry. The contemporary term "digital oral and maxillofacial imaging" has been used as the title theme to reflect the broad range of available capabilities rather than limiting the focus to intraoral imaging. This is consistent with the concept of recognizing the specialty as oral and maxillofacial radiology. The contributing authors are oral and maxillofacial radiologists familiar with the educational and clinical practice of digital radiography, a dental X-ray technologist, and representatives of the digital imaging industry. They were selected because of their expertise and interest in specific areas of digital imaging. The emphasis of the articles is upon improvements and developing research in digital technology and why, as perceived by these authors, these will influence eventual acceptance of the digital image format.

A cursory review of titles would seem to suggest that three of the articles are essentially identical. While these articles contain some overlapping information, each finds a specific path to explore. Drs. Miles, Langlais, and Parks report that "Digital X-Rays are Here" and question "Why Aren't You Using Them?" Their article is an overview of digital radiography in dentistry as it is now and what it will be in the future with emphasis upon the advantages outweighing the disadvantages. Similarly, Dr. Preston states "Digital Radiography -- Not If, but When" His report focuses upon the specific improvements that have made digital radiography much more capable of challenging and eventually replacing film imaging. Drs. White, Yoon, and Tetradis indicate "Digital Radiography in Dentistry: What It Should Do for You." They describe the practical use of digital image subtraction techniques and explain how oral radiology consulting can occur between dentists using the computer and digital-based patient records.

The article submitted by Dr. Hatcher and Mr. Dial discusses how computer technology associated with the dental imaging center has made an impact upon orthodontic, TMJ, and dental implant imaging. One feature of particular interest is the development of a three-dimensional modeling system that has the potential to significantly change future methods of treatment planning. Similarly, Mr. Woods describes a new technology recently available that makes three-dimensional images of the dental structures, which allows for a "slice-of-bread" view of a tooth. This will allow direct viewing of the furcation if one chooses. Currently, these technologies may seem remote from practical use or directed toward the specialties, but with time, refinement, and reduced initial cost, various aspects will become available for the general dental practice.

Dr. Clark and student doctors Sanz, Roxas, and Menes report the results of a survey they conducted of 34 dental insurance companies regarding use of digital radiographs and electronic image transfer for processing claim forms. Insurance acceptance of digital images is considered an important factor for developing wider utilization of digital imaging. This report provides insight into the problems and concerns that are associated with insurance acceptance and the effect that these will have upon the dental practitioner.

The primary focus of these articles has been upon technology and why it will effect the change to digital imaging. While I agree that technology is a major factor, the role of dental education was not addressed and, in my opinion, is an important reason why the change will occur. The improvements in technology, specifically sensor size and user-friendly software support, have not only increased the appeal to practicing dentists, but have also benefited dental radiography education. Traditional teaching criteria and techniques for periapical and bitewing film radiography can be applied to the digital image. As a result, several dental and allied dental training schools have introduced digital radiography into their teaching programs. This encouraged us at the University of Southern California School of Dentistry to integrate digital imaging into our September 1999 freshman dental and junior dental hygiene dental radiology course. The students were receptive, proved to be computer-literate, and breezed through the imaging software program with ease. Teaching became interactive as rapid image acquisition allowed immediate feedback from any actions made during the alignment and exposure procedures. Our experience suggests that digital imaging will soon become a regular component of all dental radiology curricula. When this occurs, students will not find it a novelty, but rather a familiar option when entering private practice. So whether or not current practicing dentists embrace the technology, certainly, if nothing else, the numbers of new digitally competent graduates entering the marketplace will increase future utilization.

As contributors to this issue of the Journal, we appreciate the opportunity to share our opinions and vision about the future role of digital imaging in dentistry. Just as film radiography ushered in the beginning of the current century, so will digital imaging commence the next. We believe the impact will be significant because once one has experienced rapid image acquisition, it is difficult to get excited about trudging off to the darkroom. So, as we collectively look to the future, hopefully, some of our comments and opinions will be considered helpful to readers in determining their responses to a new image for a new age in dentistry.

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Digital X-Rays Are Here, Why Aren't You Using Them?

Dale A. Miles, BA, DDS, MS; Robert P. Langlais, DDS, MS; and Edwin T. Parks, DMD, MS

ABSTRACT Digital imaging is here. It is cost-effective and helps dentists glean more useful information to make treatment decisions. Many more choices of digital systems are available for dentists to adopt than when the technology was introduced. The hardware is less costly than it was even one year ago, and image storage is now very inexpensive. Technical time is reduced, and no special training is required if the dentist or auxiliary has used a paralleling system. Insurance companies are gearing up to accept image files attached to claims. Why, then, are dentists not buying these systems as fast as manufacturer's can build them? This article explores that question and discusses the false assumptions behind perceived obstacles.

AUTHORS

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Robert P. Langlais, DDS, MS, is a professor in the Department of Dental Diagnostic Science at the University of Texas Health Science Center at San Antonio.

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This article presents some basic information on charge-coupled devices (CCDs), complimentary metal oxide semiconductor (CMOS) receptors and photostimulable phosphors (PSPs). It identifies available systems, reasons for acquiring this technology, and several perceived obstacles slowing the widespread adoption of digital imaging by dentists.

Also included is information on digital panoramic radiography and its potential impact of expediting dentists' acceptance of digital X-ray technology into their practices.

Digital Technology

Whether they realize it or not, most dentists have probably used some form of digital imaging. Fax machines, intraoral cameras, and home video cameras use digital technology. Digital video discs (DVDs), also called digital versatile discs, are being advertised and presented as the next major digital media technology to affect the consumer. Some dentists have already purchased such a system. And, some of the more sophisticated practices are already looking to archive their dental images – film or digital – on CD-ROM or DVD. All of these devices or systems are forms of digital technology.

A CCD is an imaging sensor, a solid state detector. It is a silicon chip with an embedded circuit that is capable of receiving X-rays (or light rays in a videocamera system) and storing them briefly before transmitting the information by electronic signal to a computer monitor for display of the image. The electronic signal is just a wave or curve that is sampled along its length so that the computer can assign a digital number directly proportional to the amplitude of the wave at a given point. The conversion of this analog electric signal to a digital number is called analog-to-digital conversion. Each digital number assigned corresponds to a particular density level or gray level of that area of the object that was imaged. Most images to be displayed on a computer monitor have 256 gray levels. Even though manufacturers claim 10 to 12 bit gray level image acquisition (1,024 to 4,096 grays), their systems can only display 8 bits/pixel of gray information (256 grays). The human eye can distinguish about 64 grays. **Figure 1** explains this process. A more thorough explanation can be found in several previously published articles.[1-3]

Direct vs. Indirect Digital Images

CCDs or CMOS receptors are also used in devices that can scan images, such as hand or desktop scanners. These devices allow a conventional film radiograph to be placed in a flatbed scanner, which captures a digital image of the radiograph. The image is only as good as the original film scanned. The production of this type of image is "indirect" because it is a secondary image scanned from the original. Some video camera manufacturers will tell you that you can make digital X-rays from their camera systems by pointing the camera at a film on a viewbox and capturing a picture of the X-ray. This is a poor technique and usually results in an inferior image because of inadequate illumination from the viewbox and trying to capture the image through the film base of the X-ray. Unless the original image is of high diagnostic quality and one uses a desktop-type scanner with a "transparency mode" specifically designed for transilluminating the image, a good image will not be produced, at least not as good as acquiring it directly by using CCD-based systems.

A direct digital image is one produced by the various commercial digital X-ray systems using a CCD as the image receptor (Figures 2a through c). **Table 1** lists current systems and manufacturers. The device consists of several layers of silicon with an embedded circuit for capturing electrons produced when the X-rays exiting the patient strike a surface layer of amorphous silicon and break a bond in the material. For every bond broken, an electron is released. These electrons are then captured in a positively charged "well" (called the electron well) for a few microseconds before an electronic "gate" (the embedded circuit) is opened and the number of electrons in each well is read out as an electronic signal.[1-3] The signal is proportional to the number of electrons in each well and accurately represents the density at a specific point or region of the object that was X-rayed. The resultant digital image is an extremely accurate representation of the anatomic region that was imaged.

CMOS Technology

The two most common types of solid state detectors available to dentists are the CCD and the CMOS sensors. WelchAllyn makes a sensor using a charge-induced device (CID), but there is very little data about this sensor. Both CCD and CMOS devices were invented in the in the 1960s, along with the transistor. Neither the CCD nor CMOS device had the commercial viability that the transistor did at that time because the computer had not yet been developed sufficiently.

CMOS chips are used in every computer. They can be made cheaper than CCD chips because the manufacturing process is very mature. As yet, CMOS detectors have not been adequately tested for X-ray image capture. CMOS chips contain some RAM operation circuitry and a microprocessor on the same silicon chip. Thus, the noise level may be greater with CMOS sensors than with CCD because of electronic "crosstalk" between the elements. Also, because there are multiple components on the same chip, there is less sensor area available for image capture. This could mean less image information in an X-ray system. CMOS detectors appear to be more suited for commercial products such as digital cameras. **Table 3** outlines the advantages and disadvantages of these sensors in terms of their technical specifications. Bold terms in the table indicate an advantage in that specification.

Figure 1. In this example, the gray level 40 might relate to the image density of the enamel, while gray level 60 represents the density of the gutta percha. There is not much difference in the density of these two materials. Tha amalgam would have a density value or gray level number of 255 - the brightest. Black would be 0.

PSP Technology

Photostimulable phospor technology may be an interim imaging modality. While the plates are wireless and the technique digital, image acquisition is still a two-step process. The plates can be processed quicker than film, but there is still a significant waiting period between image acquisition and image display. The cost of the systems is more expensive initially than CCD or CMOS systems.

The phosphors in the plate enter into an excited state proportional to the X-ray exposure; but, unlike conventional screen

TABLE 1

Current CCD-Based Digital X-Rays Systems				
Company	**Product Name**	**Thickness (mm)**	**Resolution (1p/mm)**	**Dose Reduction (vs. D-speed)**
Schick Technologies	CDR	5.0	9-10	80-90%
TREXtrpohy Radiology	RVGui	6.95	22	90%
ProVision	Dexis	8.8	12	90%
DMD	MPDx	3.2	22	90%
DentX	Sens-A-Ray 2000	6.0	>15	90%
Cygnus Imaging	Cygnus Ray 2	5.0	12	90%
Planmeca	DIXI	5.0	12	90%
Siorona	Sidexis	?	?	90%
Welch Allyn	Reveal	?	?	90%

phosphors (for example, panoramic screen/film combinations), PSPs do not immediately fluoresce to produce light photons. They only store the image information like the latent image in film-based radiography. The receptor plates are scanned in a device by a laser that excites the phosphor to give up its stored light. This light emission is captured as an electronic signal and converted to a digital image (analog to digital conversion). The digital image can then be viewed on a monitor in about 5 1/2 minutes, the time varying from the size or number of films being scanned. Image resolution is much less than with CCD receptors and ranges from 6 line pair/mm to 9 lp/mm depending on the product.

On the other hand, PSP receptors are not as sensitive to exposure time variations as film. They have an extremely wide exposure latitude; that is, they can be exposed to a wider range of exposure times and still be capable of displaying the information usefully. At about 1.6 mm, PSP plates are the same thickness as film.

Three manufacturers offer imaging systems that use PSP plates: Soredex (Helsinki, Finland, Digora), Digident (Israel, CD-Dent), and Gendex (Milwaukee, Wis., DenOptix).

Advantages

There are many articles and publications that describe the wide array of advantages of digital imaging.[1-3] Perhaps the biggest advantage from the list in **Table 2** is patient education and care. The excitement and professional acceptance regarding the intraoral camera is obvious. One of the reasons is because a picture is worth a thousand words. In many cases, the picture is worth a thousand or more dollars. Is the technology used only to generate more revenue for the dentist? In a sense the answer is yes. However, if the videocamera or, in this case, the digital radiographic image can be used to explain a problem more precisely to the patient, and the patient is educated as to his or her disease state, then, of course, the patient is more likely to accept the explanation and the treatment. This results in more revenue. This is no different than when dentists try to show patients carious lesions on bitewing radiographs on a viewbox to educate them regarding an interproximal lesion. They usually can't see it. It would be helpful to be able to display lesions on a 19" monitor so patients can discern them for themselves. Why, then, are dentists not rushing to buy CCD digital radiographic systems? There are many reasons.

Perceived Disadvantages

Cost

As much as dentists may not want to spend several thousand dollars on a new imaging device, they must examine the need for making the change very carefully. There are initial costs with both film-based and digital systems. **Table 4** is a gross comparison of the initial and ongoing costs for the first year of setting up either system. Dentists have darkrooms and use film daily and that initial cost has already been made up; but the advantages of consistency of image quality, rapid access to the images, and the ability to store them electronically and transmit them immediately by telephone more than justify the transition. The savings in office space and technical time for image acquisition and processing are also very strong arguments to switch. All imaging in the graduate Department of Endodontics at Indiana University School of Dentistry is taken with CCD sensors, stored in a computer, and written onto CD-ROMs weekly. All predoctoral dental and dental auxiliary students (both hygiene and assisting) have preclinical and clinical training in digital imaging. The move to digital imaging is inevitable.

As **Table 3** shows, the initial costs of setting up a digital system, with all the

Figure 2a. A CCD image from Cygnus Imaging (CR2).

Figure 2b. A CCD image from ProVision (Dexis).

Figure 2c. A CCD image from Schick Technologies (CDR).

Figure 4. An artist's rendering of a "miniaturized" X-ray unit placed with the grasp of the dentist or dental auxiliary.

Figure 5. A CCD panoramic image.

advantages listed, are probably less than those of a standard film-based, darkroom-dependent radiographic system. In addition, the ongoing costs, in terms of technical time, are far greater with film than with digital radiography.

Other Obstacles

There are five additional obstacles that have impeded the progress of CCD imaging in the dental office. They are:

- Lack of familiarity and use of computer-based imaging technology, especially electronic image processing;
- Ergonomic designs that are inappropriate for dentists and staff;
- Workflow needs and equipment size in the existing operatory space;
- Lack of training using advanced technology for evaluating diagnostic data; and
- Lack of an imaging software interface with true clinical functionality.

Lack of Familiarity and Use

In general, people resist change. But, dental professionals must accept change, especially when it will improve the quality of patient care. Because dental schools in North America are just now beginning to adopt digital technology into their curricula, training in this area must be done through dental continuing education by individuals with educational backgrounds, rather than manufacturer's representatives. Much of the training can be done electronically, with basic instruction for dentists and staff being placed on CD-ROMs or DVDs for in-office training. The programs would offer continuing education credits for both auxiliaries and dentists. In-office training could be done as a training day set aside in the practice. Interactive Web sites will also be used to provide digital training and practice using image processing software.

Ergonomic Concerns

Where will this technology fit in the average dental operatory? Where does one put the computer, monitor, printer, videocamera, and digital X-ray unit? One of the most cumbersome but necessary operatory tools is the X-ray tubehead. It has to be mounted on a wall, using up valuable space. Not everything can go on a mobile cart, which is difficult to navigate around the operatory, patient, and chair. The following two ideas could be useful to save valuable shelf, wall, and countertop space, and perhaps save money:

- Wireless transmission of the image or other data to the computer or monitor;
- A remote printer linked to the computer but in a central location; and
- A lightweight, portable X-ray generator to replace other tubeheads within easy reach of the operator.

Work Flow Needs

As just discussed, in most dental offices operatory space is at a premium. The X-ray machine takes up space because of the necessity for the heavy, cumbersome X-ray arm that is wall-mounted. If the X-ray unit could be "miniaturized" and placed within the grasp of the dentist or dental auxiliary, operatory space would be preserved, and the procedure itself would become more attractive and efficient. This scenario improves the workflow. **Figure 4** demonstrates this concept.

Lack of Training

Despite the advances in radiology available to the dentist, X-ray practices in the average office remain archaic. Courses in technology as old and widely adopted as panoramic radiology still draw rooms full of dentists and staff members who confide that they have never received formal instruction in the principles of panoramic imaging.

Manufacturers often succeed in bringing technology to the dentist well in advance of the dental training and education that would be useful to have in order to use the technology to its fullest advantage.

There are very few courses in oral and maxillofacial radiology that contain any digital imaging instruction. Thus, dental professionals are dependent upon the retailers of these systems for their training. This is, at best, an inadequate and possibly biased method of training, not because the manufacturers don't try their best to educate dentists about their systems, but because they cannot teach the principles of the imaging modality -- only the technique or application. Yet, for most dentists, the instruction they and their staff receive is from a sales representative with no formal dental radiology training. Without understanding the system and its principles, the dentist will be very reluctant to switch to digital imaging from film-based imaging.

Software Interfacing

Until recently, manufacturers of imaging peripherals such as video cameras and digital X-ray systems, created their own, proprietary software unique to their hardware. Now they realize they must integrate imaging software with patient management software. The dentist does not want to have to close out a task such as a patient appointment when he or she wants to look at that patient's images.

Also, all charting software is still approached as a schematic representation and only indirectly reflects the true patient status (Figure 5). What is needed is a graphic -- constructed from the specific data for the patient (bone levels, soft tissue levels, etc.) -- of the clinical and radiographic findings that is accurate and interactive. For example, when a user clicks on a feature on the patient's panoramic image, such as a restoration, the program should automatically bring up or display the periapical radiograph of that region for better detail and diagnosis. It would also be convenient to be able to "map" a panoramic image precisely to the clinical findings, so that the clinical chart would be a customized, anatomically correct version of the patient's bone status. That could be done with digital technology, and it would better reflect the way a dentist actually practices.

Digital Panoramic Technology

Even as dentists continue to debate the advantages of digital intraoral radiography for their offices, manufacturers of radiographic equipment develop new technology. Several X-ray companies have introduced panoramic machines with CCD technology, which are capable of producing outstanding images (Figure 5). Planmeca Inc., of Wood Dale, Ill., received FDA approval for its machine, the DIMAX, in August 1997 and began receiving purchase orders immediately. The CCD digital upgrade can be retrofitted to existing Planmeca EC and CC Proline models. This makes the adoption of digital technology more affordable and more attractive to those dentists who already have panoramic machines from Planmeca.

Trophy Radiology, Inc., (now Trextrophy) also makes a panoramic CCD system, called the DigiPan PC kit for adaptation to the Instrumentarium machine, the OP 100. They suggest a 360-dpi laser printer for radiological imaging. Both of these digital panoramic systems require a computer workstation with minimum requirements of 166 MHz, 32 MB of RAM, and a hard drive with 2 to 4 GB of memory.

Why Will Dentists Adopt CCD Technology Faster Than Intraoral Digital Imaging?

The answer is because unlike intraoral devices, there is no wire. Panoramic radiography does not require that the sensor be placed in the mouth. There is no difference in positioning technique or image acquisition from conventional panoramic imaging. The second reason is the image itself. The resolution of the digital images is already equal to that of standard panoramic films. CCD images have slightly less line pair resolution than film. This is not the case with the

TABLE 2

Advantages and Perceived Disadvantages of Digital Radiography
Advantages
Consistent image quality
Immediate image viewing
Elimination of the darkroom costs
Elimination of darkroom mess
Improved detection of lesions/disease
Electronic image processing
Greater exposure latitude
Remote consultation capability
Reduced exposure to X-rays
Elimination of hazardous chemicals
Improved patient education and patient care
Perceived Disadvantages
High initial cost
Storage of images
Unknown life expectancy of sensor
Special training of dental auxiliaries
CCD must be wired to the computer

TABLE 3

Comparison of Approximate Costs of Initial Imaging Systems

Company (name)	Active Area (mm2)*	Resolution** (lp/mm)	#Gray levels*** (bit depth)	Pixel Size (microns)	File Size (Kb)	Thickness (mm)	Software Interface	Service	Cost	DICOM
Cygnus Imaging (Cygnus Ray2)	949	13.5	4096/256**	25	N/A	5	Good	Good	6,995	yes
Dentsply (Gx-S)	600	>10	256	44	312	5.8	Good	Good	?	yes
Dentsply (DenOptix)^	1271	4 to 9	4096/256	N/A	N/A	1.6	Good	Good	13,146	yes
Dent-X (Sens-A-Ray 2000)	648.6	11	4096/256	45	N/A	7	Good	Good	5,995	yes
Digident (CD-Dent)^	1200	6 to 7	4096/256	60	?	1.6	Fair	?	?	?
Planmeca (DIXI)	950	11 to 22	N/A	N/A	N/A	3.2	Good	?	7,000	no
DMD (HR sensor)	929	10	4096/256	48	?	5	Good	Good	7,190	yes
Planmeca (DIXI)	819	12.5	240	N/A	71.4	8.8	Fair	Good	9,995	no
Schick Technologies (Schick CDR)	929	10-12.5	4096/256	48	120 600	5	Good	Poor	7,995	yes
Sirona (Sidexis)	?	10	?	?	?	?	Good	?	11,000	yes
Soredex (Digora)^	1200	>6	4096/256	70	234	1.6	Excellent	Good	12,400	yes
TRE Xtrophy (RVGui)	951	>20	1024/256	39	?	7	Good	?	12,450	yes
WelchAllyn# (Reveal)	1120	12	?/256	?	?	5	Good	?	7,995	yes

* The comparisons are based upon a #2 size sensor.

** Despite claims of resolution beyond 10 line pairs per millimeter (lp/mm), humans can resolve only about 8 lp/mm.

*** Despite acquiring the image in higher numbers of gray shades, all manufacturers display only 256 grays.

^ These are two-step, indirect image acquisition systems using PSPs (photostimulable phosphors).

This is the only CID (Charge Induced Device) system.

TABLE 4

Comparison of Approximate Costs of Initial Imaging Systems		
Initial		
Items	Film	CCD
X-ray tube	3,500	3,500
Darkroom	6,000	0
Computer/sensor	0	7,995
Film processor	3,500	0
Printer	0	799*
Film duplicator	600	0
Film or paper	1,500	1,500
Film mounts	500	0
Film chemistry	500	0
17,500	13,794	
Ongoing		
Film or disc costs/year	800	35
Technical time for image acquisition and processing	5,040**	2,160+
Technical time for maintenance	192 1,475	0 4,352
After Year 1	**Total 27,884**	**17,464**
Savings		**10,420**

* It may not be necessary to purchase a printer for "hard copy" if the dentists plan to view the images on the monitor and store them electronically.

**All of the tasks related to film imaging involve substantial "tech time," the cost of which is related to the auxiliary. Film costs based on an average of 15 FMX series per week for 48 weeks and a salary cost of $12/hour. Each FMX series was estimated to take 20 minutes to obtain images and 15 minutes to process and mount. Annual tech time for film = 420 hours; annual tech time for CCDS = 180 hours.)

+ Each digitally acquired series is estimated to take 15 minutes to acquire. There is no processing or mounting.

panoramic images. And, there still are all the advantages of CCD imaging; namely,

- Consistent quality;
- Elimination of the darkroom;
- Improved disease detection;
- Electronic image processing;
- Instant image viewing;
- Greater exposure latitude;
- Remote consultation;
- Reduced X-ray exposure;
- Elimination of hazardous chemicals; and
- Improved patient education and care.

Potential Drawbacks

Cost

The initial cost may be discouraging to some dentists. Because the technology is so advanced and new, the cost of a new CCD-based panoramic machine will be from $40,000 to $50,000. However, it is probable that the dentist will keep the X-ray machine for 10 to 20 years, which would be plenty of time to recoup the investment and profit from the use.

Training

Most dentists and dental auxiliaries have not had formal training in panoramic radiographic technique. The original panoramic technology was developed and marketed long before the education caught up. This has left many dentists with the opinion that panoramic images are inferior. This is not the case. Unfortunately, the sales representatives that installed the devices in doctor's offices were themselves not trained in panoramic positioning techniques. Even today, many radiologists are still asked to give one-day programs on panoramic techniques to study clubs, district dental societies, and national meetings. The fact that there is no difference in the positioning technique between conventional and digital panoramic radiography will not guarantee that a dentist will automatically have better images. Errors will still be made until the dentist and staff receive proper training. Fortunately, there are journal articles, videotapes, lectures at meetings, and well-trained company representatives to help remedy this problem. Soon there will even be CD-ROMs containing radiology training, including advanced techniques like panoramic imaging.

Computer Literacy

Training in panoramic technique is not the only educational issue. Just as with intraoral digital radiography, dentists and their staff must be able to master the image processing techniques – the electronic type – before they will feel comfortable with digital imaging of any kind. Manufacturers are aware of this and are developing image processing programs that are user-friendly. Most of the operations will be menu- and/or icon-based and easy to master quickly. The perceived problem of "techno-illiteracy" will not be a major problem for most dentists as new training programs are developed by companies to fill this void in dentist-consumer education.

Future Developments in Digital Panoramic Imaging

It is conceivable that, with two passes (exposures), software provided with the digital panoramic machines will be able to provide three-dimensional information and display, just like computed tomography in medicine. This is only possible because of the very low X-ray exposure required by CCD detectors for image acquisition. By making a second "pass" after changing the vertical angulation slightly, the software program might have the numerical information required to "reconstruct" a 3D image. This would then allow a dentist to visualize the bony defect architecture on the monitor image, rather than having to infer it from the two-dimensional radiographic images and clinical probing depths. The image could be rotated and viewed from different directions to assist the diagnosis. Dr. Richard Webber has recently developed program software to render "tomosynthetic" images -- slices through a contact point, for example -- that allow the clinician to "step through" the interproximal surface of a tooth 0.5 mm at a time from buccal to lingual. This is very powerful as a diagnostic and patient educational tool.

Integrating Intraoral and Panoramic Imaging

Digital imaging is here to stay. Both intraoral and panoramic digital imaging based on CCD systems – or reusable storage phosphors – require computer workstations and program software for image display, diagnosis, and patient education. Those practitioners who own computers are on their way to the future in digital imaging. It is only a matter of adopting the systems, acquiring some minimal additional training, and using the technology with all its advantages. There is little reason to put off the decision to go digital.

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Digital Radiography – Not If, but When

Jack D. Preston, DDS

ABSTRACT Digital radiography can enhance the dental practice by facilitating diagnosis, enabling orderly filing and archiving, and allowing better communication with patients. Although the initial investment in equipment is substantial, it is quickly repaid and provides both a substantive and fiscal benefit. There are challenges involved in implementation, but they are quickly being overcome. It is only logical for dentistry to move along with the rest of society into the digital age and take advantage its benefits.

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Change is never comfortable. Dentists spend years learning to do something well, and then a new technique comes along and challenges the comfort of the status quo. It happens with resin composites, new bonding agents, new formulations -- yet it is hard to give up something that seems to be working sufficiently. A new impression material may or may not produce better results. While change is not comfortable, it must be recognized as inevitable. One either goes forward or falls behind -- there really is no status quo. Today's dentist is faced with a myriad of changes and decisions, many of them induced by the electronic revolution. Among the decisions to be made is whether to seriously consider digital radiography.

Digital radiography is becoming increasingly more common, and the interested practitioner is faced with a variety of choices and decisions. More than 10 systems are available, all offering different features. While digital radiography has not yet become commonplace, many dentists have expressed interest in purchasing a system. The basic decisions are whether to make the move to digital radiographs and, once the first decision is made, which digital radiographic system to purchase.

Reasons not to move from film-based radiography to digital imaging are no longer valid for most practitioners. The most-often-cited reasons for such reluctance have been image quality and cost. Both of these now favor digital radiography. A third reason has been technophobia, a general resistance to entering the digital world. Perhaps this is the issue that should be addressed first.

The digital world

Children today are growing up in a digital world. They play with computerized toys, surf the Internet, and do their homework on computers. To the modern generation of children, the computer, with all its functions and interconnections, is just another accepted element of normal life. Computer software augments traditional learning methods. It broadens and facilitates communication. The computer is becoming commonplace in the home, the school, and in business. To many adults, however, the computer and computerized applications are still intimidating; and many are unwilling to face the learning curve necessary to become part of modern society. Such attitudes must change if the dentist is to remain technically competitive and be able to take advantage of devices such as digital radiography.

Consider the world in which we live. Supermarkets speed checkout using computer-based scanners and track the customers' marketing preferences in the process. Airline and hotel reservation systems are computer-based, and travelers can even make their own reservations from their computers. Investors rely on stock markets' use of computers to conduct business and can track the progress of their investments on their personal computers. The Internet has proven to be a rich and deep resource for learning, shopping, and communicating. Every substantial business is either using Internet marketing or investigating how to do so. All levels of government, transportation, commerce, and communication rely on computers. Even automobiles are dependent on computer processing. There would be no concern about the potential "Y2K" problem if computers were not ubiquitous in society. Whether we choose to recognize it or not, we all live in a digital world.

It is not a matter of if one is going to move to a digitally based office, but when. If one chooses to remain technophobic and not make the transition to the modern world, it is a conscious choice to be left behind, to stand out as an anachronistic relic of the past. The decision to be made, then, is how to effectively implement digital technology into a dental practice.

Image Quality

When digital radiography was introduced into dentistry, the quality of the images was less than desirable. Furthermore, sensors were bulkier but had active surface areas smaller than that of traditional film. Users were forced to accommodate these limitations. This has changed. Today sensors are available that are the equivalent of the commonly used film surface area and have a comfortable thickness (**Figure 1**). Several digital radiography systems offer sensors in sizes commensurate with the surface area of traditional film, including No. 0 for pediatric dentistry, No. 1 for anterior periapical images, and No. 2, the universally used size for most imaging. The physical dimensions are easy to compare, but comparing diagnostic quality is more difficult.

When comparing a digital image with film image, it is generally assumed that the film image has been acquired by selecting the appropriate voltage, amperage, and time, and that the properly exposed film was also properly processed (including adequate fixation and drying) and appropriately filed. Such films are

Figure 1. Modern sensors are less bulky and more comfortable than their predecessors. The sensor shown is 3.2 mm thick.

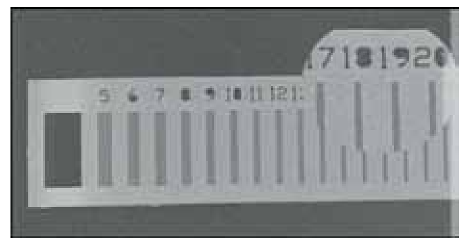


Figure 2. A radiograph of a line pair phantom. The magnified inset shows that at 20 line pairs/mm, the separation of lines and spaces is still clearly visible.

rarely found in the real world. Film is commonly viewed without magnification and evaluated using only ambient light. If a film image was not properly exposed or processed, and does not have optimum contrast and brightness, the dentist is forced either to make a new image or to accept a less than desirable image. Because of time constraints, the latter choice is usually made. However, a digital image can be manipulated to compensate for less-than-optimal exposure variables and is always viewed in a larger format than film. Furthermore, it can be greatly magnified (the extent of the maximum magnification is dependent on the inherent pixel size of the sensor) and can be otherwise optimized without sacrificing original image integrity. Contrast and brightness can be varied to focus on the different features in the image.

Quantifying Image Quality

The term resolution is often used to compare film and digital images. Resolution measurements attempt to quantify the smallest observable details. It is often referred to in terms of "line pairs" -- the use of an imaging instrument having successively smaller pairs of radiopaque lines. Direct digital imaging (as opposed to phosphor plate technology that has lower resolution) offers resolution from about 11 to more than 20 line pairs (**Figure 2**) while film is generally considered to resolve 15 line pairs. The unaided human eye can only see 9 line pairs, but the enhanced resolution becomes a factor upon magnification. Sensor resolution greater than 20 line pairs has only recently been possible.

Resolution is only one aspect of the diagnostic quality of either film or digital images. The large format of the digital image makes visualization easier and enhances communication with patients. Once one becomes accustomed to viewing images on a large monitor rather than peering at a small film on a viewbox, it is difficult to return to film.

Dynamic range -- the blackness of blacks, whiteness of whites, and continuous tone of a complete gray scale -- is essential for adequate diagnosis. Nearly all direct digital systems provide 256 grays, the greatest number the human eye is capable of distinguishing.

Signal-to-noise ratio quantifies the strength of the signal to the background electronic noise. When magnified, film is quite "noisy." Digital radiography systems use signal amplification and background noise subtraction to produce the cleanest possible image.

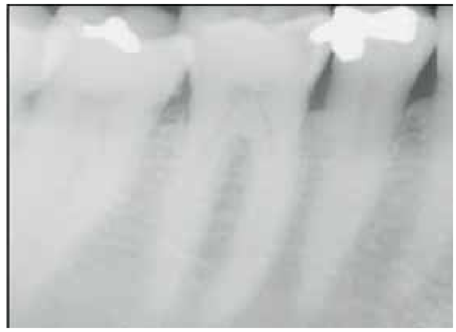


Figure 3a. This image was underexposed.

Figure 3b. A simple change of contrast and brightness produces an image that is of diagnostic quality.

Figure 4. The rectangle in the main image identifies the region of interest. The inset "picture-in-picture" is a 2x magnification of the region. In reality, this image would be at least the size of this journal page rather than the small format shown.

Pixel Density

Sensors are made up of a series of electronic "wells" that trap electrons. The number of electrons in each well translates into gray-scale images. The size of these wells varies with different sensors. A typical sensor will have electron wells approximately 45 m m square. Unlike film, where crystals are randomly arranged and of various sizes, the sensor has ordered rows and columns of electron wells. Each of these is an element in the image that is produced: a picture element, or a "pixel." The smaller the pixel, the greater the number of points of information that can be displayed on a screen. High-resolution sensors with pixels one-fourth the typical size are now available. Four pixels of 22.5 m m will fit into the space occupied by a 45-m m -square pixel. Therefore, the pixel density of the high-resolution systems is four times greater than the standard systems. This will manifest as a finer grain image but will not be greatly visible until the image is magnified. High-resolution images may be magnified more greatly without breaking up into visible pixels (pixelating). Sensors with more than a million pixels (megapixel sensors) are available from at least two sources, and others are sure to follow.

Regardless of what technical methods are used to make a comparison, probably the only means of really equating the diagnostic equivalency or superiority of digital images comes from the daily use of film and sensors and appreciating the quality of today's digital diagnostic systems.

Cost

Once diagnostic equivalency has been shown, the second factor to address is cost. Film carries both direct and indirect costs. The cost of the film itself, the cost of processing chemicals and space in which to use them, the cost of waste disposal, the cost of automatic film processors, and, not insignificantly, the time it takes to process and store film all must be considered. Add to this the time required for cleanup and maintenance, and it becomes apparent that the time consumed by film radiography is significant. Rather than construct a scenario that might or might not apply to the reader, it is suggested that each reader calculate the number of films made each day in his or her office; the time consumed by the assistant, hygienist, or dentist in processing, mounting, and cleaning; and especially the cost of waiting with a patient for a film to be processed so a procedure can continue. Endodontics, implant dentistry, dowel post placement, oral surgery, and similar services may all require sequential imaging during a procedure, and waiting time can be substantial. Using these numbers, it is easy to demonstrate that the cost of digital X-ray system can be recouped in less than a year -- with many added benefits.

With digital radiography, there are no chemicals to purchase, store, or dispose of. There is no film to carry in inventory. There are no mounting procedures and no filing or loss of images. One of the great advantages of digital radiography is the orderly filing of images, with the ability to retrieve by tooth, region, or date.

Radiation Reduction

Virtually everyone realizes that digital radiograph images require less radiation to make than film. The decrease in radiation burden is usually cited as a comparison to D speed film, since the comparison is more favorable. When the purpose of the film is to establish some gross feature, such as the position of a file in a canal, or the length of a dowel post, a radiation reduction of up to 90 percent over D speed film is possible. For more discriminating diagnosis, evaluating margins or small carious lesions, higher exposures are needed; but in any event, the radiation dose will be less than either D or E speed film.

What is important is the latitude of the system. Over how wide a range can an acceptable image be made? With a wide latitude, it is simpler to get a diagnostic quality image. It is better to err on the side of underexposure, since overexposure may cause “burnout” -- loss of image information as a result of electrons spilling out of a capture well into adjacent areas. With slight overexposure, the majority of the film will be of diagnostic quality, but some areas will be unusable.

Remaking Images

There is another issue related to radiation reduction, and that is the re-exposure to obtain the desired image. Sometimes an image must be remade, either because the film or sensor has been mispositioned, or the X-ray cone was misdirected. Remakes may be necessitated with either film or sensors. However, when remaking a film image, the film has been removed from the mouth, several minutes have passed since it was exposed, and the chances of making a proper image the second time are not greatly better than they were with the first exposure. With a digital image, the image is displayed almost immediately, the sensor is still in position, and the X-ray tube head is still in place. Remaking the image becomes much more predictable, since the sensor or tube head can be moved from a known position to the desired position.

Image Transmission

One of the great advantages of digital radiography is the ability to export images. This is an advantage not only for sending radiographs to third-party payers but for many other purposes. Duplicate radiographs -- whether single images or a complete mouth series, have the same quality as the originals -- at no added cost, and with virtually no additional time. These can be sent to a referring dentist or forwarded to any other treating dentist.

Legal Issues

Concerns have been raised about the legal aspects of a virtual image, and the potential for image alteration (falsification). There are now image-tagging algorithms that mark images as being original and unaltered. Such images may be enhanced (brightness, contrast, etc.) but may not have any alteration of the image information. Such images may be transmitted and used with assurance that, as long as the image tag guarantees the image is unaltered, the image is secure. Of course, neither film nor virtual images can preclude the outright fraud of sending images for different patients or other flagrant falsification.

High-Speed Communication Services

When transmitting multiple images, data transfer speed becomes an issue. Whereas “plain old telephone service,” commonly referred to as “POTS,” may be adequate for small files and infrequent transmission, if larger files are frequently sent, the office should consider other communications systems. Urban areas have many options, including Integrated Services Data Transmission (ISDN), Symmetric Digital Signal Lines (SDSL),

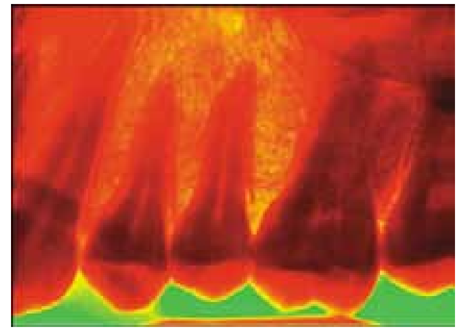


FIGURE 5. A combination of the "invert" and "colorize" features accentuates trabeculation and provides an almost 3-D appearance.

and cable. Whereas POTS is able to send messages at no greater than a nominal 56 kilobits/second (actual transmission can be much slower), SDSL and cable can send and receive 1.5 million kilobits per second. SDSL and cable service may cost as little as $30 per month and provide Internet service 24 hours a day, seven days a week. Such service is economical, especially when compared with some telephone company services such as a T-1 line. Asymmetric Digital Signal Lines (ADSL) and satellite transmission offer only one-way high-speed transmission -- to the office, but not upstream from the office. Satellite may be an economical alternative in areas where the preferred services are not available, but input data will only move at the available modem speed.

With proper software, digital images and files can be accessed from a home computer if an emergency arises. Images may also be sent via the Internet as attachments. The destination for the image is irrelevant. It can be across the hall or across an ocean.

Similarly, images can be printed in a letter to patients or in communication for referral. Some specialists, especially endodontists, routinely send back images of pre- and postoperative radiographs embedded in a referral letter. Some digital radiography software facilitates such communication by linking to form letters that can be written with images appended directly from the original program.

Image importing and exporting

Modern digital radiography software allows the user to import images from attached devices such as a scanner or a digital camera. In this way, film radiographs may be accurately scanned, enhanced when necessary, and digitally filed as a part of the patient's virtual chart. Other documents such as prescriptions, medical reports, or laboratory work requests can also be scanned and filed. Intraoral camera images may likewise be archived with the radiographs in a patient chart, graphically chronicling the patient's treatment and documenting progress.

Configuration

Most dentists who do not have a computer network already installed envision beginning with digital radiography as a cart-based or portable system. The probability of a digital radiography cart being pushed from room to room is not great. Historically, those who bought intraoral cameras on a cart either did not use them or eventually supplied all the operatories with cameras.

The dentist who wants to test digital radiography may well start with a cart, but it is unlikely that the cart will be frequently moved. Another way to set up a mobile system is to use a laptop computer. Several such systems are available, using either PCMCIA slots or universal serial bus (USB) ports. Such systems make movement from room to room fairly easy, and the large hard drives on modern notebooks makes image storage reasonable for the short term. However, once images are acquired and patient folders begin to accumulate, the serious user must consider networking and linking to a practice management and virtual patient record system. It makes no sense to isolate patient X-ray images on a computer that is not interfaced with other records. In an office where the hygienist or other associates will also be using the system, isolation is unthinkable. In such situations, a digital network is a reasonable, viable solution. Once computers in the different operatories are linked, patient files can be shared and are easily accessible by everyone authorized to view them. When a practice management system and virtual patient treatment record are added, the full facility for acquiring and archiving information is present.

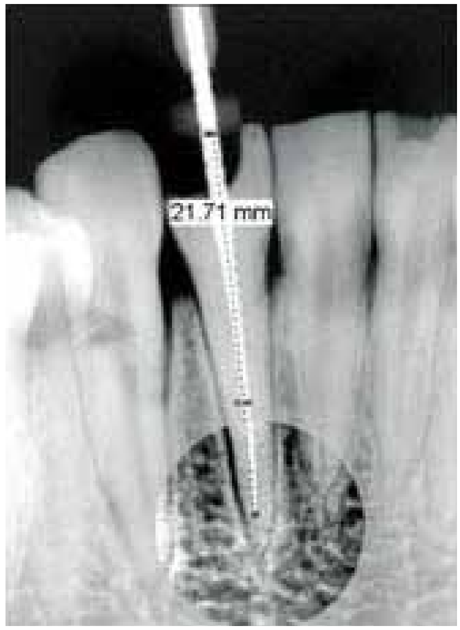
The thought of integrating all records is intimidating to many dentists, and the idea of linking some other software to their practice management system brings looks of horror and disbelief. It is true that in the past such integration has been problematic and unreliable with some systems; but, with well-written software and a stable network, such integration can be seamless and smooth.

When considering a network installation, one should remember that image transmission requires greater bandwidth (ability to pass information) than does text alone. Fortunately, networking costs, as most computer-related costs, have dropped; and a high-speed (100 Base T) network is the only reasonable consideration.

Image size

As previously mentioned, high-resolution images have greater pixel density. This means larger file sizes, which affect storage capabilities. Since the legality of image compression is still unclear, it is safest to opt for lossless compression, in which no image information is discarded. Some digital systems have image storage capabilities

Figure 6a. A file placed in a mandibular lateral incisor is short of the apex.



Figur e 6b. The apical region is spot enhanced to better locate the tip of the file and the apical foramen. A measurement is made from the stop to the tip of the file.

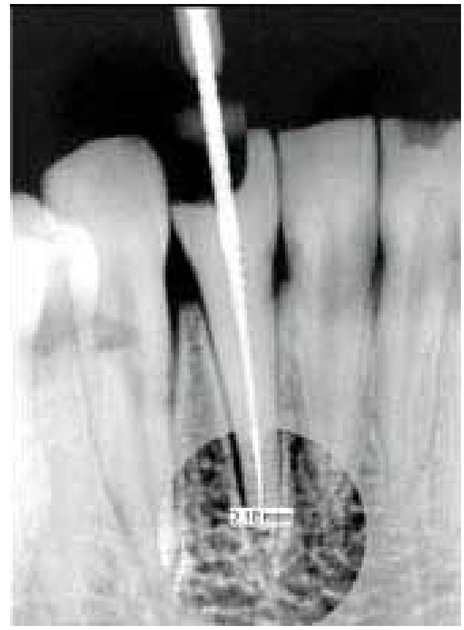


Figure 6c. The remaining distance from the tip of the file to the apical foramen is determined.

that guarantee an original image but at the expense of maintaining a larger file. Fortunately, hard disk sizes continue to grow while costs drop. In planning storage capabilities, one should take into consideration the average number of radiographs made weekly, the file size for each image, and the total file requirement to store images each year.

Archiving

Since X-ray images are a part of the patient's dental record, they must be archived. If one calculates the number of patients treated each year, and the number of images that each patient represents, simple multiplication will indicate a data storage problem. Images not in active use may be archived on CD-ROM, digital tape, or another server. Before long, off-site digital storage will be available at a reasonable cost and with easy access. When high-speed data transmission is coupled with off-site digital storage, the data storage and access problem is nicely solved.

Image Capture

Part of the intimidation factor of progressing from film to digital radiography is the change in both format and function. The procedures for obtaining film images are so routine that there may be some reluctance to try anything that would be more demanding. Fortunately, many current systems simplify image acquisition with little deviation from current film-based procedures. The first noticeable difference between film and sensors is that sensors are rigid: They cannot be bent. Operators frequently bend film to accommodate oral conditions, with resultant image distortion. Thus, the rigidity of the sensor can be thought of as a positive factor in that it prevents distortion by bending, even though it requires accommodation to some oral conditions.

Sensors also require a barrier cover, since they cannot be autoclaved. Some sensors are provided with plastic barriers, others with natural rubber. The barrier should cover both the cable and the sensor -- anything that contacts the patient. Some attention should also be given to the receptacle in which the sensor will rest between uses, inasmuch as this is also a potential source of cross-contamination. A disposable insert is desirable.

Sensor positioners should accommodate either a paralleling technique or a bisected angle approach. Positioners should also allow for root canal instruments to remain in place during the imaging. In short -- the system should allow the user to continue the same practices currently used with film.

Image capture should involve as little interaction with the computer as possible. Some systems are able to sense the radiation and display the image after being initially activated, minimizing any computer interfacing. The great benefit of digital images is the ability to immediately display the image, whether it is a single image or part of a complete mouth series. The user may choose to accept the image or correct the alignment and remake it.

Once the procedure for image acquisition is learned, users usually find it as simple as using film, without waiting for the image, and with no need to develop, fix, or dry the image.

Image Enhancement

Digital radiography software systems offer a plethora of image manipulation algorithms, some of which are rarely used. There are many advantages of image enhancement that should be mentioned. The most common is alteration of contrast and brightness. **Figure 3** shows an image that was underexposed but which was easily and quickly manipulated to improve diagnostic quality.

Magnification is another frequently used feature. Instead of holding a film up to a light box and using loupes or a magnifying glass to see more detail, digital images may be magnified simply and easily. The pixel density of the image determines the degree of magnification possible without the image breaking up into pixels. High-resolution images with small pixels permit higher magnification. **Figure 4** shows an area of an image enlarged two times, yet the visualization is greatly enhanced.

Colorization is frequently shown by those demonstrating digital radiography, but it is usually of only casual interest for diagnostic purposes. Colorized images are created by assigning a color to a range of grays, and the process actually discards some information. However, colorization can be helpful in defining soft tissue and, when combined with image inversion (reversing black and white), often shows trabecular patterns remarkably well (**Figure 5**).

Other combinations of features can also be helpful. Measurements are often needed when performing endodontic therapy or placing a dowel post. Nearly all digital systems facilitate measurement. Measurements can not only be linear, but can also navigate root curvatures. Spot-enhancing the area accentuates contrasts and aids visualization. **Figure 6**a shows a file in a canal and short of the apex; **Figure 6**b shows the apex spot-enhanced, and the measurement made from the stop to the tip of the file. **Figure 6**c depicts the spot-enhancement with the distance from the file tip to the apical foramen. Such measurements are difficult with film. In addition to having to wait for the film to be processed, the potential for measurement error is greater.

Image enhancement can greatly facilitate both diagnosis and treatment procedures. Digital radiography also improves communication, since the patient can be shown the large image and can see features impossible to appreciate with film. Text labeling, drawing on the image, and other communication devices help patients to visualize problems and understand the necessity of therapy.

Summary

Digital radiography facilitates and enhances diagnosis, enables orderly filing and archiving, and allows better communication with patients. Although the initial investment may seem substantial, that sum is repaid within the first year of use and actually provides both a substantive and fiscal benefit. It is only logical for dentistry, along with the rest of society, to move into the digital age and take advantage of the profound benefits that the virtual world offers. The question the practitioner should be asking is not "Why should I use digital radiography" but, rather, "Why should I use film?"

Digital Radiography in Dentistry: What It Should Do for You

Stuart C. White, DDS, PhD; Douglas C. Yoon, DDS; and Sotirios Tetradis, DDS, PhD

ABSTRACT Digital radiology will become an important part of dental practice. Manufacturers should develop more sophisticated tools, including software for digital subtraction; image processing routines for the diagnosis of caries, periodontitis and periapical disease; tools for three-dimensional viewing of the teeth and supporting structures; and analysis of bone trabecular pattern for early detection of systemic disease. Hardware improvements should include increased dynamic range and sensitivity to radiation, and improved resolution. Sensors should be made the size of film, and components should be interchangeable across manufacturers. The true opportunity offered by digital imaging, computer-aided diagnosis, should continue to develop with particular attention to development of tools that add value for solving diagnostic problems and ease of use for the dentist and patient.

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The 21st century will be the digital era of dental imaging much as film imaging dominated the 20th century. The early signs are clear. About 6 percent of general dentists and 30 percent of endodontists already own direct digital radiographic equipment. In 1994, the National Library of Medicine indexed two articles under the subject of "digital dental radiography"; this number rose to 50 by 1998. This trend is expected to accelerate. Immediate benefits of digital capture include time efficiency, patient education, radiation reduction, and environmental compatibility. More importantly, the future opportunities are immense. Incorporation of telediagnosis, videoconferencing, and transmission of images among and between dentists and insurance companies will be rapid. Additionally, digital imaging will become inextricably linked to electronic patient records (patient management systems) offering improved quality assurance to the dentist.[1,2] A complete electronic patient record will include all visual and audio information in a seamlessly integrated, easily retrievable and user friendly format. Computer-aided diagnosis will become routine practice in clinical dentistry. The potential of digital imaging is only beginning to be explored. It is important now to identify clinical problems where this technology can best assist the dentist in providing improved diagnosis and treatment planning. Dentists should play an active role in establishing their needs and proposing solutions to help guide intelligent development of this powerful diagnostic tool. This article will discuss problems of four major areas of dental practice that should be addressed by digital imaging:

- Image display and analysis;
- Computer-aided diagnosis;
- Hardware development; and
- Administrative applications.

Image Display and Analysis

One of the most exciting advantages of digital imaging is its inherent capability for manipulation of the display and analysis of the image. Once a digital image is acquired, whether through a charge-coupled device (CCD) sensor, storage phosphor plate, or scanner, its presentation may be readily manipulated to enhance features of diagnostic interest. Further, the image may be analyzed for patterns characteristic of disease. Various forms of analysis, measurement, feature extraction, image enhancement, and artificial intelligence techniques will be developed to improve the diagnostic acumen and work productivity of the dentist.

Subtraction Radiography

The basic technique of subtraction radiography is to make two radiographs of the same region of the jaws at different times. The first image may then be subtracted from the second to look for changes in the object occurring during the time interval, such as a loss of bone associated with periodontal disease or a gain in bone following successful therapy. In a controlled laboratory environment, digital subtraction allows small amounts of mineral gain or loss to be detected, much smaller amounts than can be recognized by simple visual examination of the before and after radiographs (**Figure 1**). In practice, however, subtraction radiography is limited by the need to reproducibly image the patient with the same geometric relationship among the X-ray source, jaws, and image receptor, either film or digital. If the two views are made with different geometric perspectives, they cannot be properly aligned at the time of subtraction. Also, the process of image alignment or registration can be fairly tedious. In recent years, a significant body of techniques has been developed to deal with these problems. Placing the patient in a cephalostat with a fixed X-ray source and coupling the film to the teeth with impression compound help to produce images with reproducible image geometry. However, faster and less complicated methods are needed for application in dental offices. Mathematical tools are now available for correcting between changes in density and contrast due to film processing between the two images.[3] Most recently, tools are being developed that will automatically recognize anatomic features and then rotate, translate, and scale the images for automated image registration.[4] These tools will save the dentist time and improve alignment accuracy.

Digital subtraction should become increasingly useful for early detection of disease and measurement of disease progression or resolution following therapy.[3,5-11] In particular, digital subtraction has been used most frequently for evaluation of periodontal disease progression.[6,7,12,22] When used skillfully, it provides a more sensitive method to detect early bone loss than conventional radiography. For similar reasons, subtraction radiography has been used for caries diagnosis.[10,23] The tools for reproducible beam/patient/receptor alignment should be improved. Software tools for image registration, contrast correction, and subtraction radiography are available and should be built into digital systems.

Contrast Manipulation

Currently, images captured by digital sensors or digitized from film are displayed with minimal amounts of image processing. Most manufacturers of digital systems also provide tools for the dentist to modify sharpness, brightness, and contrast of the image. There is increasing evidence, however, that more-sophisticated image processing tools may improve the image such that the dentist is better able to identify caries, marginal periodontitis, or other diseases. Techniques such as unsharp masking, nonlinear stretching, and adaptive histogram equalizations, though currently time consuming, hold promise as aids for detecting dental disease (**Figure 2**), especially if automated. There is already evidence that such tools may manipulate the image display so as to provide improved visualization of conditions such as caries,[24] periapical disease, and periodontal disease.[25-27] More effort should be made to develop the diagnostic potential of these techniques.

Among expected developments are "smart" tools, which segment an image into distinct anatomic regions and then apply image enhancements specific to each region or disease. For example, tools may be developed that automatically identify:

- Crowns in order to highlight occlusal and proximal surface caries;
- Tooth roots above bone to detect root caries;
- The alveolar crest to evaluate the character and location of the marginal periodontium;
- The periapical regions to assess the thickness of the periodontal ligament space and the integrity of the lamina dura; and
- The cancellous bone and trabecular pattern to evaluate for local or systemic disease.

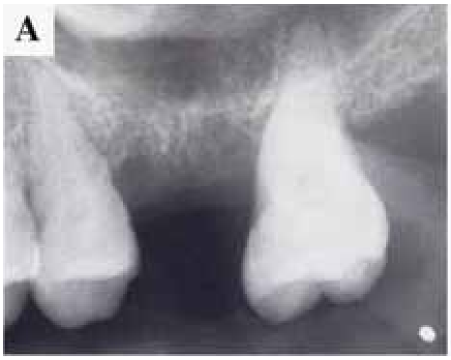


Figure 1a. In digital subtraction radiography, the differences between two radiographs are revealed. Image A was made immediately after extraction of a maxillary molar.

Figure 1b. This image was made one month later.

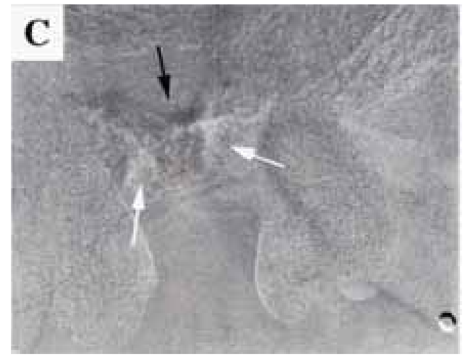


Figure 1c. The subtraction of Figures 1a and b reveals areas of bone loss in black (black arrow) and bone deposition in white (white arrows).

For each of these regions, different image processing techniques may be used to optimize the presentation of the image to enhance diagnosis. Further, as discussed below, individualized analysis of the features of each image segment (e.g., bone, enamel, root), can be automated to screen patient images for evidence of disease.

Color

Color in digital imaging adds value to intra- and extraoral images. Starting at the basic image acquisition level, stable and accurate color rendition will be essential for diagnosis (e.g., soft tissue lesions), treatment (e.g., prosthodontic shade selection and cosmetic tooth color matching), and longitudinal comparison of color changes. Manufacturers of both intra- and extraoral digital cameras should adhere to automatic image color calibration with monitors to ensure uniformity of image display.

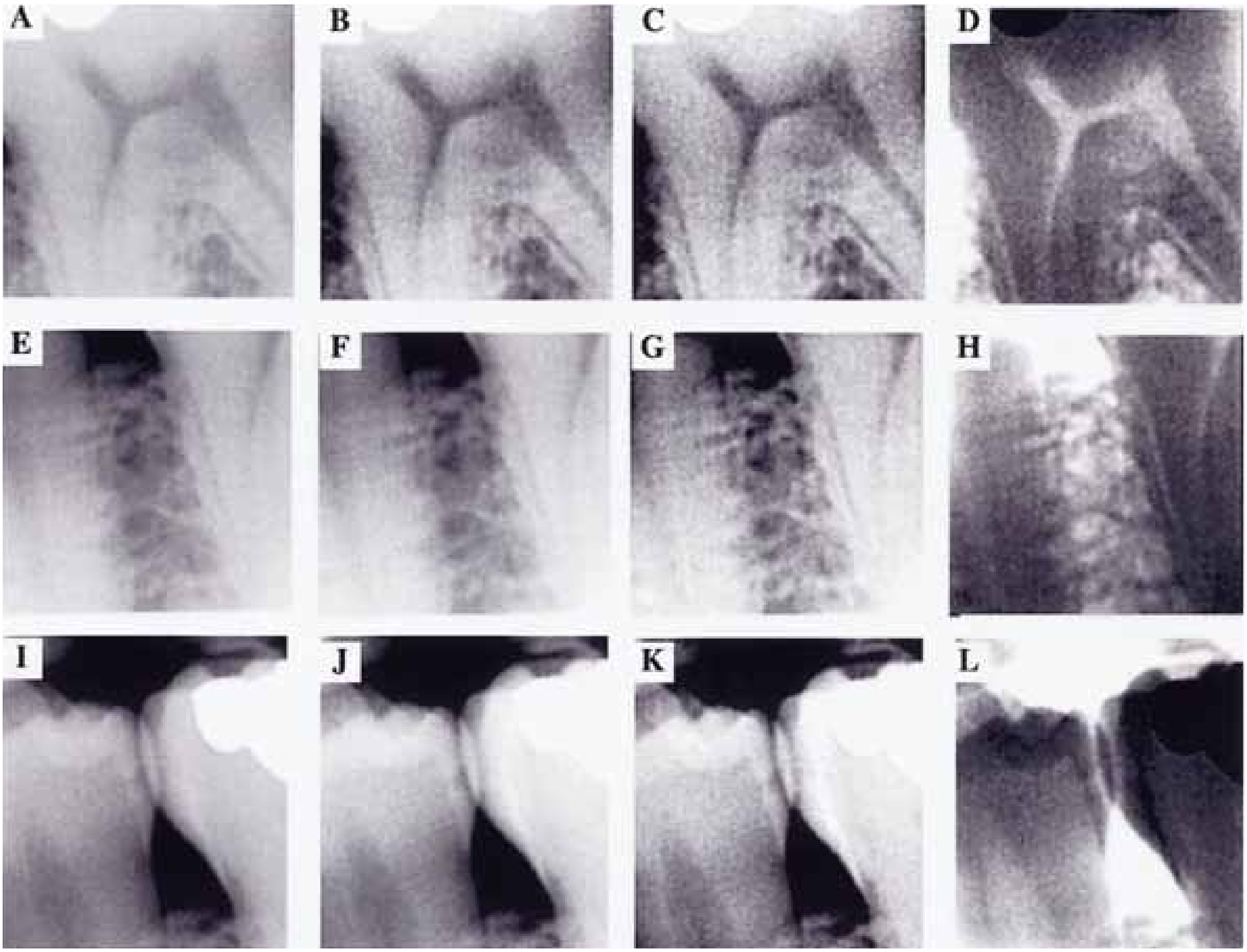
Currently, pseudocolor is being applied to digital radiographs. This technique assigns a color depending on the brightness value of a pixel. The eye is sensitive to many more colors than shades of gray; thus, the goal is to add discriminative power to the image by replacing gray level images with pseudocolor. However, the resultant image is not usually satisfactory for diagnosis because one type of structure – e.g., dentin or bone – may assume different colors. With image processing, structures of similar composition may be made to appear comparably in pseudocolor (**Figure 3**). Recently color coding has also been usefully applied to subtraction radiography so that the color represents the amount of brightness gain or loss.[28,29] Thus, there is considerable opportunity for improvement in the use of color for intraoral radiographs.

3-D Reconstruction and Display

The digital format will allow reconstruction of three-dimensional displays instead of the standard two-dimensional images. Reconstruction is a powerful diagnostic concept because it allows views from perspectives that are impossible to obtain by conventional means. Already, Tuned Aperture Computed Tomography (TACT) imaging allows tomographic reconstructions of thin image slices through teeth and bone.[30-32] Additionally, more advanced systems are being developed that will use multiple two-dimensional images to provide computer tomography (CT) like cross-sectional displays of teeth and bone, as well as three-dimensional surface renderings (**Figure 4**). Such images may be quite useful for identifying periodontal defects,[33] root fractures, the spatial relationship of impacted teeth to anatomic structures and other teeth, and potential implant sites.[34] These images will become available in dentistry within a few years at reasonable prices. It is also expected that the patient doses from these examinations will be much closer to that of a conventional full-mouth X-ray than a CT examination. It is expected that when these imaging modalities become available, static image viewing will rapidly give way to interactive 3D-image manipulation and presentation.

Artificial Intelligence

Artificial intelligence has been applied to many aspects of dental diagnosis.[35] Common examples include programs that evaluate a patient's signs and symptoms and generate a differential diagnosis. For example, a program called ORAD has been developed to assist the dentist in forming a differential diagnosis of a radiographic lesion.[36] It is available on the Web.[37] This program relies on a decision support system using Bayesian theory. With this method, the user enters a patient's signs and symptoms, and the program returns a list of diseases, in order of probability, that may account for the findings. ORAD considers 16 clinical and radiographic variables such as patient age; location of the lesion in the jaws; and the size, contents, and borders of the lesion. The program has a database of 140 lesions and uses Bayesian logic to evaluate these clinical features to arrive at a differential diagnosis. While most dentists recognize



Figures 2a through l. With image processing anatomic features can be better visualized. The three images in the left column (a, e, i) were obtained from a storage phosphor system. In the second column of images (b, f, j) the originals have been contrast stretched to use the full range from white to black. In the third column (c, g, k) unsharp masking has been added to the images in the second column to enhance edges. In the fourth column (d, h, l) the images from the third column have been inverted. Note particularly how the alveolar crest is visualized against a white background rathar than a dark background.

common diseases on radiographs, this program is often useful because it may suggest unusual lesions consistent with the clinical presentation or unusual manifestations of common lesions.

Computer-Aided Diagnosis

Currently, diagnosis of early disease is often difficult. Digital imaging may improve decision making by providing dentists with a wide variety of decision support (computer-assisted diagnostic) systems.[38-41] Because digital images are composed of pixel brightness values, programs have been written that measure these values and search for expected features or patterns. Automatic recognition of intrinsic disease features will provide powerful objective diagnostic tools to the dentist. Computer-assisted diagnostic programs will be helpful in several areas, including:

Caries Diagnosis

Caries diagnosis is difficult, especially in lesions limited to the enamel or near the dentoenamel junction. A number of investigators have developed programs for automated caries recognition.[42-50] These programs evaluate the density of the enamel and dentin, typically in vertical strips paralleling the proximal surface, and look for a reduction of density indicative of caries. Recently, a commercial product, Logicon Caries Detector by TrexTrophy, performs analysis of the density profile of proximal surfaces of teeth and identifies surfaces likely to have caries. The utility of this product is awaiting independent validation. Future development should be directed toward recurrent, root surface, and occlusal lesions.

Periodontal Disease

Loss of alveolar bone is a radiographic hallmark of periodontal disease. Periodontal disease progression, measured either through loss of density or height of alveolar bone, should be developed as an automated tool for early disease identification and evaluation of treatment success.[12,19,51,53] Subtraction radiography should most likely be a part of this package.

Periapical Pathology

Detecting periapical disease at its early stages is often difficult, particularly when associated with the buccal roots of maxillary molars. Automated morphologic analysis of the details of the apex, including width of the periodontal ligament space and integrity of the lamina dura, will assist the dentist in early detection of periapical disease.[54-56] Similarly, measurement of changes in the size and density of periapical lesions could allow early assessment of the success of endodontic treatment. For these endodontic applications, subtraction radiography will add significant analytic power.

Implantology

Implants are now an established means of replacing missing teeth. A number of software programs that reconstruct CT images to allow cross-sectional viewing are available. New low-dose techniques are being developed, while tools to assess bone quality and quantity prior to implant placement should be created. In addition, means to rapidly assess the extent of osseointegration and alveolar bone loss following placement need to be established.[32,57-59]

Orthodontics

In orthodontics, CCD and storage phosphor digital imaging receptors are being used.[60-62] There is a clear need for consistent automatic landmark identification of cephalometric images followed by craniofacial analyses of growth and development.[63-66] These and other features will save the dentist time and improve the quality and consistency of diagnosis and treatment planning.

Bone Disease

The jawbones are the most frequently imaged bones of the body. Their morphology is altered by local stimuli, systemic diseases, and metabolic disturbances. Digital radiography allows early identification of osteoporosis and other metabolic diseases of bone[67-76] Although this field is in its infancy, analysis of morphologic features, such as the trabecular bone pattern of dental radiographs (**Figure 5**), will provide a valuable screening tool for patients with early abnormalities or progression of bone diseases.[77-80]

Hardware Development

In film-based radiology, the radiographic film is both the sensor and the display. In digital radiology, the sensor and the display are separate, which allows the manufacturing of digital sensors with improved characteristics over film. However, film has many useful imaging properties that digital sensors should mimic or extend.

Dynamic Range

The dynamic range of a sensor is the range of radiation exposure that may be recorded, from the highest dose that produces a black image to the lowest dose that produces a light gray barely detected by the eye. A sensor with a wide dynamic

Figure 3a. Pseudocolor is available on most, if not all, digital radiographic software. This is a digital image made from a storage phosphor system.

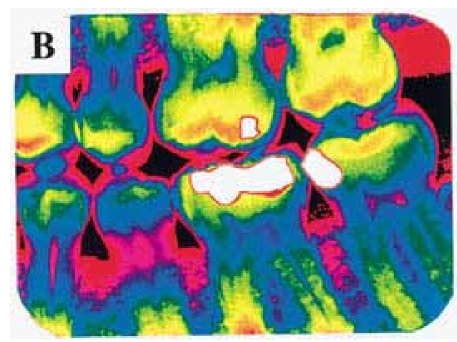


Figure 3b. This is the same image with color applied according to the gray scale. While cosmetically attractive, the image is less diagnostically useful than the original.

Figure 3c. This image shows pseudocolor applied to the top image after image processing to make similar structures appear with comparable colors. Note how all the marrow spaces are pink and the bone trabeculae are blue. Even with this method, however, the original image, Figure 3a, remains the most diagnostic.

range is highly desirable in clinical practice because it can produce a diagnostic image over a wide exposure range; it can detect small density differences of the imaged object and accurately record objects on the same image with high and low attenuation. Film has a relatively narrow dynamic range of about 1,000-to-1.[81] That is, the exposure that causes the film to be very black is 1,000 times higher than the exposure that causes the film to be a light gray. CCD sensors show an even shorter dynamic range than film, i.e., about 100-to-1.[81] Thus, when exposures are too high or too low, CCD sensors are more likely to have diagnostically meaningless light or dark regions on an image. The dynamic range of CCDs will have to improve to better address these important issues of diagnostic dental radiology. The best sensor with respect to dynamic range is the photostimulable phosphor with a ratio of greater than 10,000-to-1 ratio of high vs. low detectable radiation exposure.[82] Photostimulable phosphor sensors are reported to provide diagnostic images over a wider range of exposures than film or CCDs.[83] Although this is a major advantage because it eliminates the need to repeat images due to overexposure errors, it should be addressed with caution because it hides the danger of systematically overexposing patients.

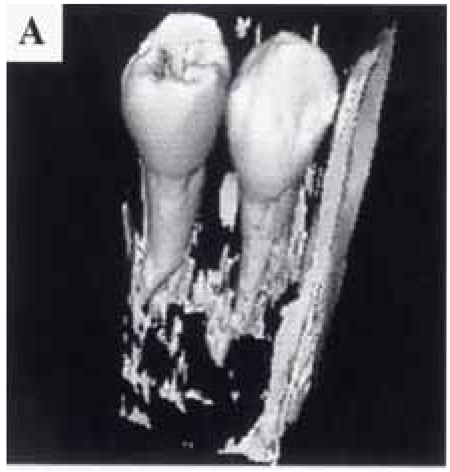


Figure 4A. Multiple two-dimensional images can be combined mathematically to reconstruct a variety of views, including surface rendering, as in this figure (image courtesy of Drs. P. van der Stelt and S.M. Dunn).

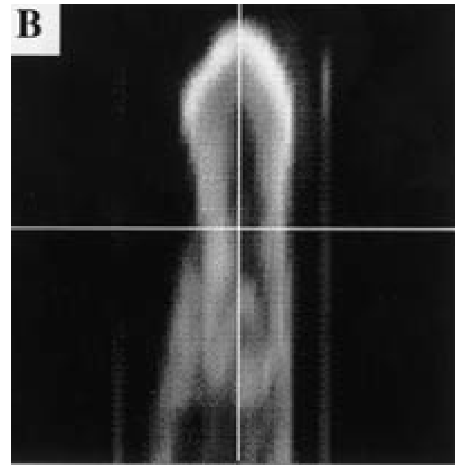


Figure 4B. Two dimensional images were used to create this bucco-lingual section through a tooth (image courtesy of Drs. P. van der Stelt and S.M. Dunn).

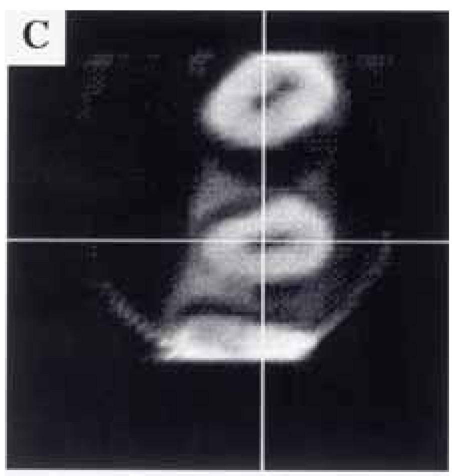


Figure 4C. This figure shows an axial section of a tooth (image courtesy of Drs. P. van der Stelt and S.M. Dunn).

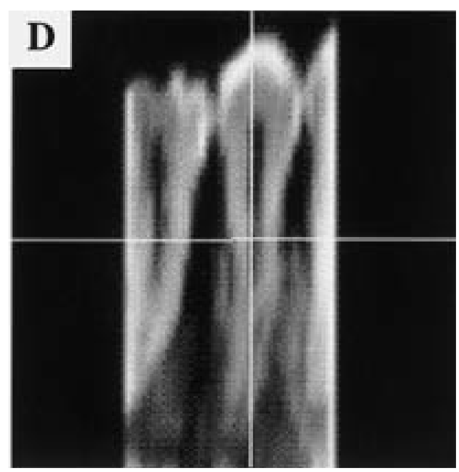


Figure 4D. This figure shows a mesio-distal section of a tooth (image courtesy of Drs. P. van der Stelt and S.M. Dunn).

Dose Response

Another performance characteristic of the image sensors is the response to radiation exposure. A linear response means that the resulting image density increases or decreases in direct proportion to the amount of the X-ray exposure. The response of film to radiation is not linear. In contrast, both CCD and photostimulable phosphors have a linear response throughout their dynamic ranges of exposure. A sensor with a linear response is desirable and advantageous in clinical practice because it offers a better distribution of levels of gray at low and high densities and allows a predictable quantitation of an object's attenuation. New sensor technologies should strive for a linear response.

Sensitivity

High sensitivity to radiation exposure is an important characteristic of the image sensor. Sensitive sensors require less radiation to produce a diagnostic image and thus reduce the radiation received by the patient. CCD and photostimulable phosphor sensors are more sensitive than film. Their use reduces patient exposure approximately in half compared with E-speed film and to one quarter compared with D-speed film. Further development toward increased sensitivity is desirable as long as image quality is maintained

FIGURE 5A. Image processing can be used to measure particular features of cancellous bone. This image shows a portion of a conventional radiograph in the anterior maxilla.

FIGURE 5B. This image is a blurred version of Figure 5a.

FIGURE 5C. This figure shows the subtraction of Figure 5b from Figure 5a. This levels out the bright and dark areas so trabeculae show with a uniform density across the entire image.

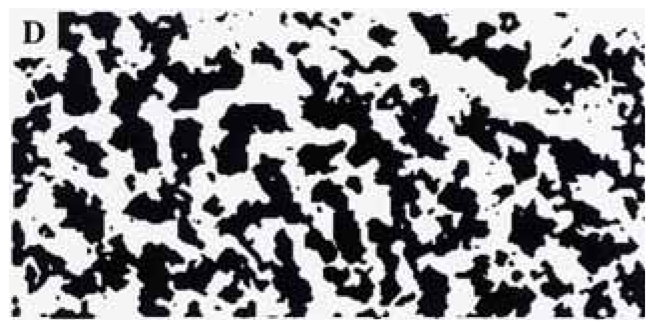


FIGURE 5D. This image is a thresholded version of Figure 5c; that is, trabeculae made wihte and marrow made black.

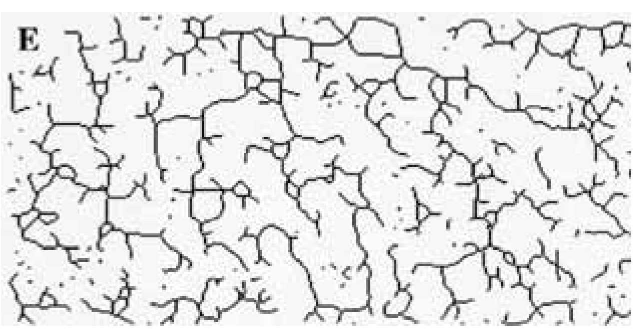


FIGURE 5E. This image is a skeletonized version of Figure 5d to show the core structure of the trabeculae. This skeletonized image can be measured to reveal properties of the trabeculae such as the length and branching structure.

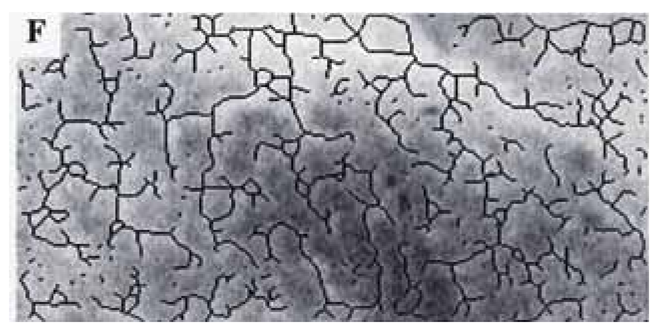


FIGURE 5F. This image shows the skeletonized image in 5e superimposed on the original image (Figure 5a) to show the congruence of the two images.

or improved. As faster sensors become available, X-ray generators will need improved timers for accurate control of short exposure durations.

Signal-to-Noise Ratio

Signal-to-noise ratio is defined as the ratio of the receptor output (film density, charge, or luminescence) that is related to diagnostic information compared to the output without diagnostic information (noise).[81] Low noise is a characteristic of a good sensor. A good sensor should be able to detect the diagnostic information in the remnant X-ray beam and separate it from the noise originating from the imaging system. An inherent and unavoidable source of noise in dental radiology comes from the statistical fluctuation of photon density in the X-ray beam. The recording medium (e.g., film or direct digital sensors) adds additional noise. Digital images add an additional source of noise from the various electronic components of the imaging system. In general, the lower the noise, the more sensitive the sensor is to radiation. Film is considered to have a higher signal-to-noise ratio than CCDs. Manufacturers of digital sensors should continue their efforts to minimize electronic noise and thus improve the detection of diagnostic information. Commensurate with improved signal-to-noise ratio, also expected is the development of digital imaging systems with increased contrast resolution employing 10 or more bits, much like current CT displays. This will increase the number of gray levels from 256 to 1,000 or more. Such an increased range will allow windowing and leveling adjustments to gain optimal viewing of dentin, enamel, and bone.

Resolution

Spatial resolution is the ability of a sensor to detect as separate images two objects that are placed close together (**Figure 6**). Until recently, film offered the highest resolution of all sensors. Now several companies are offering digital sensors with resolving capability in excess of 20 line pairs per mm.[84] It is likely that more companies will soon provide comparable products. The available photostimulable phosphor sensors have a resolution of approximately 10 lp/mm. Sensors with higher resolution should be manufactured to assist clinical practitioners in everyday tasks, such as identification of root canals or root fractures. Improved resolution will allow greater magnification of images and improved diagnosis.

Density Standards

Incorporation of density standards into receptors will allow accurate measurement of object mass leading to measurement of mineral gain or loss, such as in caries or periodontal or periapical disease. Changes in bone mass may also be useful for detecting disease progression or resolution. In this fashion, radiography will advance as a precise quantitative diagnostic tool. Trends in this direction are evident in the research in absolute calibration.[9] These technologies must still be adapted into user-friendly clinical software.

Size Formats

Drawing upon the successful standardized configuration of film-based imaging, manufacturers of digital systems should strive for similarly sized formats of the viewable surface area. Because of their unique sealing and packaging requirements, the proportion of viewable surface area for CCD and complimentary metal oxide semiconductor (CMOS) systems tends to be less than for film. However, the major difference between film and CCD or CMOS sensors is their thickness. Compared with film, which is about 1.6 mm thick, current CCD and CMOS sensors are about 7 to 8 mm thick, not counting the cord attachment of these devices. Storage phosphor sensors are similar in area and thickness to film and, like film, are somewhat flexible and do not have attached wires. There is a strong perception by many clinicians that decreased thickness enhances patient comfort. This remains to be verified by clinical studies.

Component Modularity and Standardization

Uniform standards of data formats and component interfacing should be adopted. The lesson learned from the development of the PC industry in the 1980s and 1990s is that closed architecture and proprietary data formats may result in short-term financial gains but that such products ultimately suffer from the inability to work with complementary technology. Medical digital imaging has shown the way by establishing the DICOM Standard to foster compatibility among competing digital systems. Thus, it is essential for the practicing clinician and the future health of the digital imaging industry that standards of interfacing be adopted. To start with, sensors should be interchangeable. This would give the clinician the ability to easily replace broken sensors even if the original vendor has gone out of business and to easily upgrade to new sensor technology without investing in an entirely new system. It is also clear that office integration is the trend for electronic technology of the future. Based on current trends, it is reasonable to assume that, in the future, practice management software will assume a major role in office integration. To survive in this environment, producers of digital imaging technology must seamlessly integrate with practice management software. This will require adoption of standardized image file formats and I/O (input/output) protocols. For example, the DICOM Standard for medical imagery and the Twain model for I/O interfacing are likely candidates. In this regard, the emerging dental DICOM format is a likely candidate.

Ergonomics

The digital imaging technology of the future will need to continue to address clinical ergonomic issues. In addition to the issue of sensor size discussed previously, imaging systems of the future will need to improve chairside accessibility. Cords draping across the patient can impede typical dental procedures. Thus, there should be a move toward wireless systems or compact image storage systems (e.g., electronic or storage phosphor-based). Facilitating this process will be improvements in office networking. Clinicians currently are concerned about

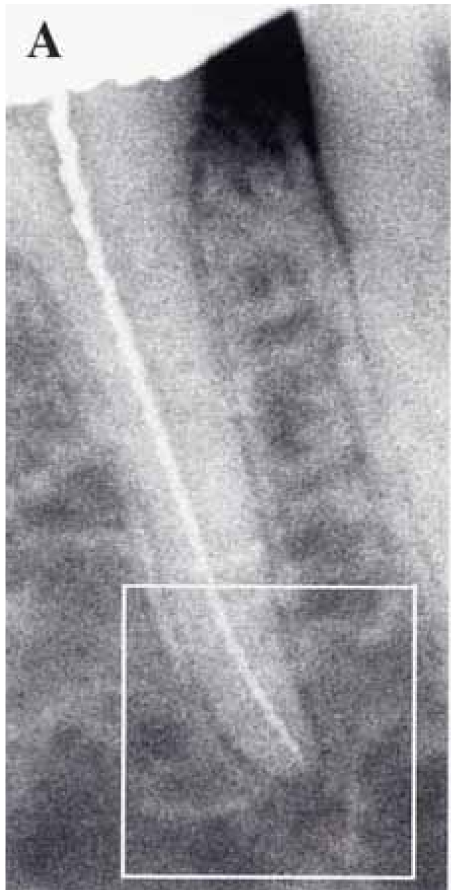


Figure 6a. Image resolution is important for viewing fine detail. This is a portion of a conventional radiograph. The apical region (in white box) is shown in Figures 6b-d.

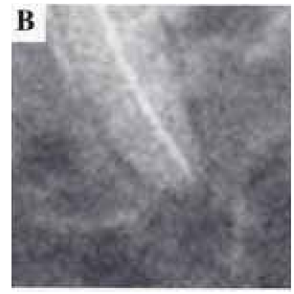


Figure 6b. This image was scanned at 5 line pairs/mm.

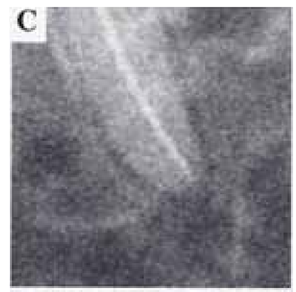


Figure 6c. This image was scanned at 8 line pairs/mm.

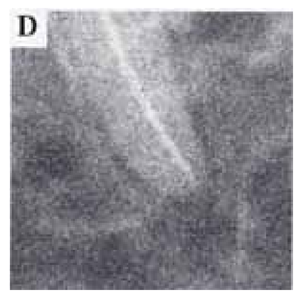


Figure 6d. This image is at 16 line pairs/mm. Note the progressive increase of fine detail and edges with increased resolution. For many tasks, however, high resolution is not necessary.

already crowded conditions exacerbated by the proliferation of computer hardware in the dental operatory. Networking has provided some relief for this problem and this trend will continue. The offices of the future should have small, simple client PCs and flat-screen monitors integrated into the chair with easily accessible interface ports mounted on the tray, much the same as handpieces are mounted today. Larger, more powerful machines at the front desk can handle all sophisticated digital processing.

In the future, all patient data collection, recording, and retrieval operations should be voice-activated and integrated though a centralized patient management system. This will significantly streamline charting, history taking and radiological examinations. This hands-off approach will not only speed up operations by freeing up the dentist and assistant's hands, but will also facilitate infection control.

Administrative Applications

Advances in digital imaging technology should allow streamlining of many of the clinical administrative operations that involve visual information. These operations will benefit from the enhanced speed of transmission of visual data, encryption security and automated quality control that digital electronic technology affords. The following are examples of near-term applications of digital technology to administrative operations.

Teleradiology

A significant near-term application of digital imaging technologies lies in teleradiology. That is, the electronic transmission of digital radiographic images for purposes of remote education and radiological consultations. Improvements in transmission bandwidth and the explosive growth of the Internet make remote consultations possible to any office possessing a computer, flatbed scanner, and modem. Software designers should build in the tools to give the dentist the capability of easily transmitting images to colleagues for real-time consultations.

Electronic Insurance Filing

Most major companies, including dental insurance companies, will move toward paperless operations because of potential cost savings associated with reduced paper work. The software that accompanies digital systems should provide the tools to facilitate interacting with these "paperless" companies, including the capability to electronically attach radiological and other imagery.

Pattern Recognition

Many previously labor-intensive operations such as billing and scheduling have been integrated into commercial practice management software. This trend will continue with the integration of digital imagery into patient records. Sophisticated pattern-recognition technologies should be developed to enable automatic recognition of teeth and image projection. This will enable automated filing and retrieval of radiographs in the patient records according to tooth number. Pattern recognition technologies will also assist in ensuring quality control (including detecting cone cuts or excessive radiation exposure) during the radiological examination.

Security

One of the major concerns regarding electronic data especially digital imagery has been security or data integrity. This perception stems from the ease with which images may be digitally manipulated. However, electronic conversion of image data actually affords some of the most robust forms of security based on sophisticated mathematical encryption and encoding algorithms. For example, sensitive authentication algorithms can detect the smallest change in a digital document following its creation. For instance, the DICOM Standard used in medical imaging includes Digital Signature, software to allow authentication and verification of an unaltered DICOM image. Conversely, robust watermarking algorithms can identify the original source of a digital document despite extensive manipulation of the image (e.g., Digmark Photoshop plug-in software). In conjunction with bonded agencies, these tools should be incorporated into dental imaging to provide all parties with the necessary security to prevent fraud and lack of confidence in the technology.

Conclusions

The future imaging world will be quite different from the current one. The integration of digital imaging into the patient record must become seamless, both in terms of use and technical support. The true opportunity offered by digital imaging – computer-aided diagnosis – should continue to develop with particular attention to development of tools that add value for solving diagnostic problems. We are on the cusp of a paradigm shift in dental digital imaging that is full of opportunities for commercial and academic endeavors. The clinical dentist should be an integral part of this process.

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Dental Imaging Centers

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ABSTRACT Dedicated dental imaging centers have been providing valuable imaging services to the dental community for many years. The centers feature specialized and sophisticated imaging equipment and highly trained personnel and provide photographic and radiographic services for the community. This article discusses selected sophisticated imaging equipment found in dental imaging centers and discusses current and anticipated future services provided by the centers. These future services include the construction of patient-specific interactive three-dimensional models to be used for diagnosis, treatment planning, treatment simulations, communication, and evaluation of treatment outcomes.

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Dentistry has historically relied on imaging technology to assist with diagnosis, communication, treatment planning, treatment simulation, and evaluation of outcomes. Until recently, radiographic images have been acquired in general or specialty practice offices. During the past 10 years, there has been an emergence of sophisticated independent dental imaging centers. This article will discuss the role of imaging centers in the dental community, including the role of radiology personnel and the key services provided by these centers. New developments and future goals for imaging centers will also be discussed.

The recent development of designated imaging centers can be attributed in part to the highly specialized imaging equipment and uniquely trained staff that are currently used for imaging. In general, it is no longer economical for an individual dental office to provide the comprehensive services of an imaging center; and, therefore, these services are commonly being referred to a dedicated imaging center. Such centers are most common in the western half of the United States, and California has the highest density. The high density of referring dentists in large metropolitan areas make them ideal sites for imaging centers. Several new centers are being planned for underserved areas in the western half of the United States and Canada. Technological advances in imaging are occurring at a rate faster than can be reasonably assimilated into a private practice, which creates the opportunity for an imaging center to offer advanced imaging services to the dental community.

Imaging centers provide photographic and radiographic images that become an essential part of the patient record and are used to aid in diagnosis, treatment, and assessment of outcomes. Imaging centers do not provide treatment and, therefore, do not compete with the services provided by referring dentists. Imaging centers typically service numerous referring dentists and their patients within a geographic area. They work closely with referring dentists to provide images that are optimal for their individual treatment approaches and maintain archived records for future reference. Imaging centers provide a referral slip that lists available services and facilitates the referring of patients. They also participate in local study groups to present and discuss new technologies or methodologies. The services of an oral and maxillofacial radiologist may also be provided to interpret radiographic images.

Personnel

Dental X-Ray Technologist

Modern dental imaging requires personnel who are highly skilled and well-trained. This is partially necessary because sophisticated new X-ray units require the operator to have excellent computer skills and extensive training. To utilize the equipment effectively, the technologist must have a thorough understanding of new technology such as digital capture, digital scanning, sensor technology, digital cameras, and digital printers. Sophisticated X-ray units are complex and require a high skill level for operation. Dental X-ray technologists have specific training required to perform maxillofacial imaging. Licensing guidelines in California allow the dental X-ray technologist to perform imaging services without the direct supervision of a dentist or oral radiologist, but services can only be performed if accompanied by a written or oral requisition. Dental X-ray technologists receive approximately 2 1/2 years of specific training in radiography. This specialized training provides the technologist with the skills, knowledge, and ability to perform the most sophisticated dental imaging.

Oral and Maxillofacial Radiologist

Oral and maxillofacial radiology was recognized by the American Dental Association's House of Delegates in October 1999 as a specialty, the first new one in 36 years. An oral and maxillofacial radiologist is educated in providing radiographic interpretation of maxillofacial images, including radiographs, CT scans, magnetic resonance imaging, and tomography. Most imaging centers are associated with radiologists who provide radiographic interpretations and technical advice. Oral and maxillofacial radiologists are specifically educated and trained to apply the most appropriate technology for diagnostic purposes for such conditions as temporomandibular joint disorders, infectious diseases, tumors, dental abnormalities, and trauma.

Radiographic Studies

The decision to acquire images occurs as a result of discoveries at the time of the clinical exam and history. There are many available imaging options that can be used in clinical investigations. These include periapical, bitewing, panoramic, cephalometric, tomography, CT scan, magnetic resonance, and bone scans. The ideal imaging solution produces the desired diagnostic information while minimizing the cost and risk to the patient .[1] The ability to fulfill these imaging goals is currently limited by the ability of imaging modalities to represent the anatomy in three dimensions. Imaging centers perform all imaging studies that would normally be performed in a dental office as well as specialized studies requiring sophisticated equipment. The following is a description of some of the equipment and special studies provided by these centers.

FIGURE 1. CommCat, a robotic tomographic unit produced by Imaging Sciences International.

FIGURE 2. A submental vertex projection used to plan the location of the tomographic sections. The tomographic sections are planed to be perpendicular (green lines) and parallel (yellow lines) to a line extending between the medial (orange marker) and lateral poles (yellow markers) of the condyles.

Specialized Equipment

Digital and Robotic Equipment

Computer-controlled motion control systems for tomographic and panoramic/

cephalometric imaging have recently become the cornerstone pieces of equipment for dental imaging clinics. The CommCat tomographic unit (Imaging Sciences International, Hatfield, Pa.) (**Figure 1**) and the OP-100 panoramic/cephalometric unit (Instrumentarium Imaging, Milwaukee, Wisc.) are examples. These robotic imaging units have been designed to image the structures of maxillofacial regions from multiple points of view. Alignment of the X-ray tube and the targeted anatomy occurs via computer control of stepper motors. The computer is the interface that the radiology technologist uses to perform panoramic or tomographic studies. The technologist uses the computer to provide study-specific movement instructions to the imaging instrument, and in turn the instrument produces images that are optimized for the study. There are options to retrofit all film-based imaging systems, including panoramic, cephalometric, and tomographic systems, with a digital sensor. The imaging sensor types include a charged couple device (CCD) and photo-stimulated phosphor sensor. These sensors eliminate darkroom processing procedures and produce a digital image that can be viewed on a monitor, transmitted via Internet or World Wide Web, archived, and printed.

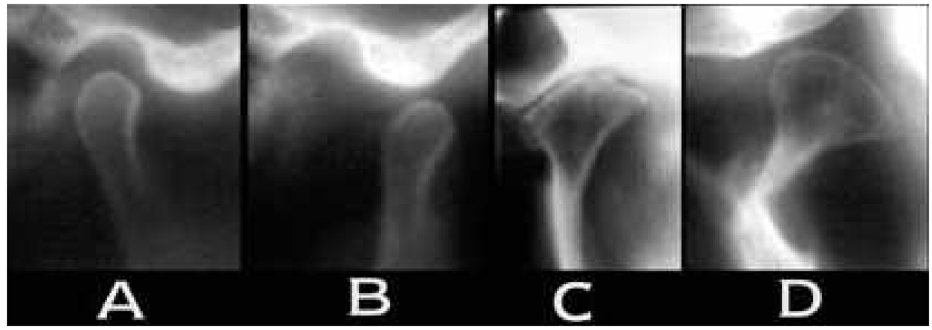


Figure 3a. Figures 3a through d show axially corrected tomographic sections of the temporomandibular joint. Figure 3a shows a para-sagittal image in the closed mouth.

Figure 3b. Figure 3b shows a para-sagittal image in the open mouth position.

Figure 3c. Figure 3c shows the TMJ with evidence of degenerative joint disease and narrowed joint spaces.

Figure 3d. Figure 3d shows a subcondylar fracture with a medial displacement of the proximal fragment.

Specialized Studies

Tomography

Site-specific imaging refers to imaging techniques selected to optimally show specific anatomic regions, such as maxillary sinuses and TMJs. The ideal images show the area of interest with at least two views at right angles to each other produced with minimum superimposition and maximum detail. Tomography is an exceptionally good site-specific imaging technique because it provides high quality images at the desired projection angulation, at low risk (exposure), and relatively low cost. Tomography is a general term used when an imaging technique provides an image of a layer of tissue.[2] These layers or planes can be oriented to acquire any desired slice of the anatomy under study. The versatility of this technique makes tomography highly desirable for accurate imaging of a wide variety of maxillofacial structures, including the TMJ and cross-sections of the maxilla and mandible.

TMJ Tomographic Study

Corrected tomography has been one of the most widely used techniques to examine the hard tissue of the TMJ because of its ability to image the TMJ quickly and relatively inexpensively. Axially corrected TMJ tomography refers to the alignment of the tomographic beam with the mediolateral long axis of the condyle to produce image layers that are parallel or perpendicular to the mediolateral long axis of the condyle (**Figure 2**). The laterosuperior and mediosuperior surfaces of the condyle are more difficult to image than the central two-thirds of the condyle with sagittal tomography. Therefore axially corrected para-coronal plane images are recommended for viewing these surfaces.[1]

The initial goals for TMJ tomography are to show the size, morphology, and quality of the osseous components and the condyle/fossa spatial relationships in the open and closed mouth positions. To best meet these goals, the tomographic sections must be acquired in planes parallel (para-coronal) and perpendicular (para-sagittal) to the long axis of the condyle (Figures 3a through d). Each section should be thin, approximately 2 to 3 mm thick, and acquired with a complex motion to reduce blurring. Images should be taken with the patient in an upright position.

Implant Tomographic Study

Corrected tomographic sections provide imaging information that optimizes placement of endosseous implants that enhance the success of all subsequent stages of implant placement, including the long-term success. The specific information provided by tomography that increases the long-term success of the biointegration and function of these implants includes jaw size (height and width), orientation of the vertical long axis of the jaw, jaw boundaries, internal anatomy, soft tissue morphology, bone quality, and pathological processes affecting the implant site.[3]

To provide optimal information, tomographic sections should be acquired parallel and perpendicular to a tangent point on the jaw curve and perpendicular to the occlusal plane (**Figures 4 and 5**). Similar to TMJ tomographic studies,

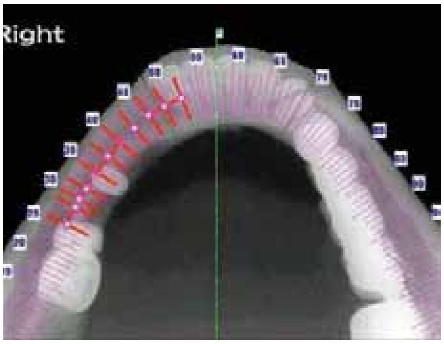


Figure 4. An occlusal film used to plan the location of the implant sites. The jaw curve and proposed location of tomographic sections were mapped onto the occlusal film parallel and perpendicular to a tangent point on the jaw curve.

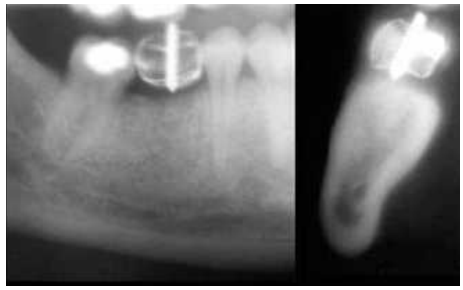


Figure 5. Implant tomographs acquired perpendicular and parallel to a point on the jaw curve identified by the metallic marker located and oriented along the path of a proposed implant. The tomographic sections are oriented perpendicular to each other and can be corrected for magnification to allow for accurate measurements of the anatomy. An acrylic tooth coated with a thin layter of barium sulphate supported the metallic marker. The acrylic tooth and marker are used to test the feasibility of this site for implant placement (courtesy of Dr. Monica Crooks).

each tomographic section should be thin, approximately 2 to 4 mm thick, and acquired with a complex motion to reduce blurring. Images should be taken with the patient in an upright position

Photographic Services

Imaging centers provide intraoral and extraoral photo documentation services. Historically these services have been provided with a 35 mm single-lens reflex camera optimized for dentistry, but more recently 35 mm cameras are being replaced by megapixel digital cameras. The photographs can be previewed for quality while the patient is still present. The image is then downloaded into a computer and formatted into a mount series (**Figure 6**). The images can be catalogued, stored, and printed on photographic-quality paper. The digital camera provides several benefits over standard photography, including the ability to print additional copies from the original photographic series. Any archived digital photographs can be selected and included in a word processing document, such as an interpretative report, or in a presentation package.

Figure 6. This mounted photographic series was acquired with a megapixel digital camera. This digital image series or any portion of this series can be printed on phtographic-quality paper, archived for future use, incorporated into word processiong documents, or used for presentations.

Software Enhancement of Standard Series

X-ray film or photographs can be digitized using a flatbed scanner with a transparency adapter or a digital camera. These digital images can be used with software programs to provide additional information. For example, Surgical Planner Software (Imaging Sciences International) (**Figure 7**) is an interactive software program used by the treating dentist to aid in the diagnosis, treatment planning, and presentation of implant cases that have been imaged with the CommCat tomographic unit. The tomographic images are digitized and prepared by the imaging center and the image files are transferred

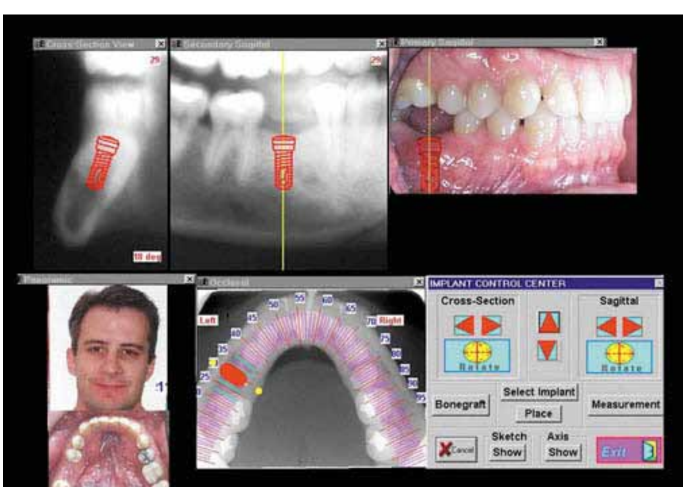


Figure 7. A series of digital images displyed in SurgPlan, an implant planning software program by Imaging Sciences International. This is an interactive software program that corrects the images for magnification and spatially cross-correlates selected anatomic sites. This program allows access to and the simulated placement of a database of implants categorized by manufacturer and size.

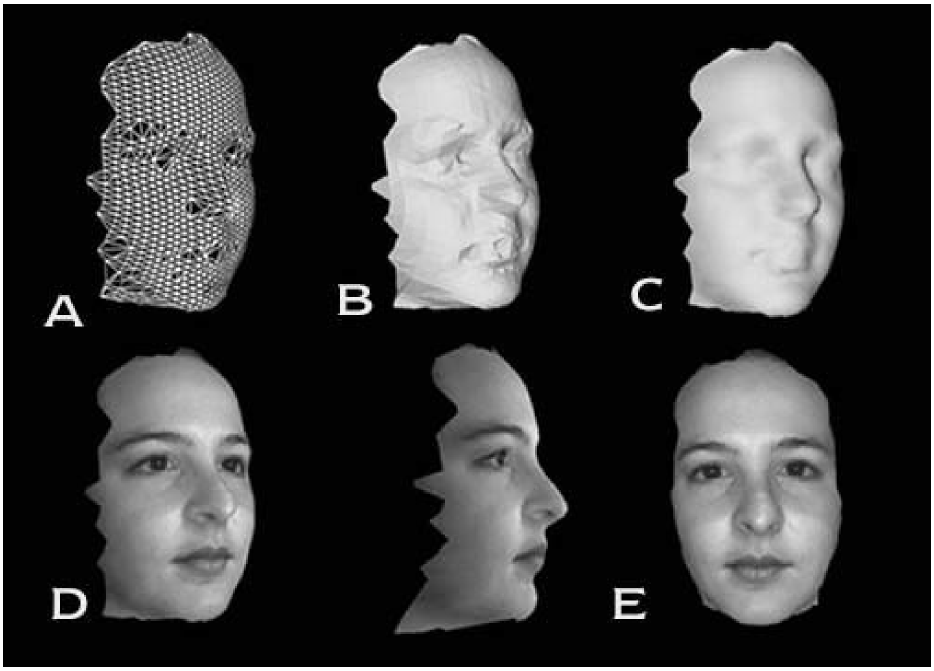


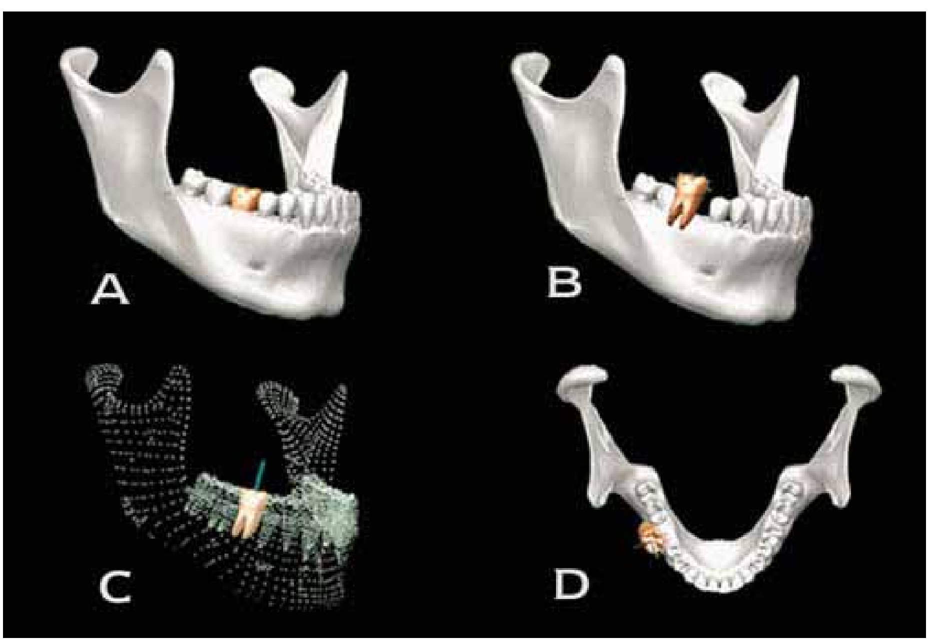
Figure 8a. This series of three-dimensional digital images shows the stages of model construction using a three-dimensional camera that employs structured light. Figure 8a shows a series of points (vertices) that have been connected with lines to form a polygon mesh. The three-dimensional locations of the vertices are being continuously computed as this object is displayed and rotated.

Figure 8b. The polygon mesh has been tiled to provide a surface to this object.

Figure 8c. The tiled polygon mesh has been smoothed.

Figure 8d. The tiled polygon mesh has been textured with the patient's photograph.

Figure 8e. A rotation of the three-dimensionally rendered face.



Figures 10a through d. An Acuscape model of the mandible and mandibular teeth. The mandible and teeth have been segmented into individual objects. The locations of these objects, with six degrees of freedom relative to the global patient reference planes, are being continuously computed as the objects are moved during dynamic modeling, treatment simulations and viewing.

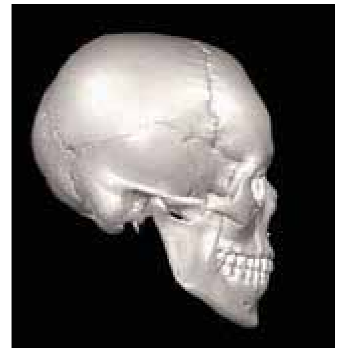


Figure 9a. A surface-rendered model of a patient's skull.

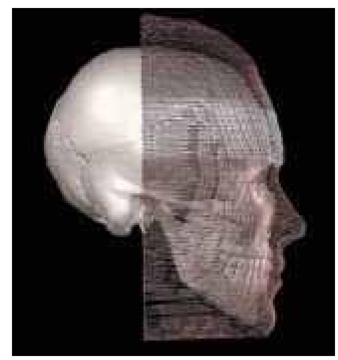


Figure 9b. The skull from Figure 9a and a spatially accurate registration of a polygon mesh of the facial soft tissues.

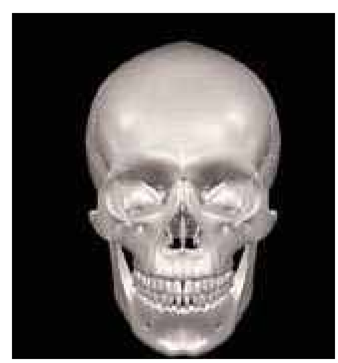


Figure 9c. The skull from Figure 9a rotated to a frontal view. These patient models were created using Acuscape Sculptor software from a standard series of two-dimensional cephalometric and digital photographic projections. Acuscape's Sculptor program was used to spatially calibrate, register into a three-dimensional matrix and measure these images.

to the doctor via the Internet or softcopy to be used for diagnosis and treatment planning.

Future Goals and Services

The goal of imaging is to display the "anatomic truth" as it exists in nature. Current technology is limited because it represents a three-dimensional object in two dimensions. All two-dimensional images are acquired from a selected point of view (e.g., lateral cephalometric projection). These projections create images with superimpositions and dimensional changes in anatomy because of the projection geometry used to acquire them. Anatomy can be obscured because of the chosen projection geometry. To overcome these limitations, multiple modalities are combined to produce a "patchwork quilt" image of the patient. For example, multiple types of images such as periapicals and photographs are used to view the teeth; orthogonal cephalometric projections are used to view the facial skeleton; photographs are used to view the facial soft tissues; and corrected tomographs are used to view the TMJs. Each of these views has its own limitations due to projection geometry, superimpositions, and obscured anatomy. For the clinician to understand the three-dimensional anatomy, he or she must perform a mental reconstruction of the patients' anatomy using all of the available images. New technology or software programs that aid the clinician in creating a three-dimensional computer reconstruction of the patients' anatomy would be beneficial. New imaging input devices and software programs are being developed to provide three-dimensional data that will enable the development of accurate three-dimensional anatomic models.

Future Input Devices

Intraoral and extraoral digital cameras utilizing structured light or lasers will be available within months. These cameras will enable the three-dimensional reconstruction of the surface anatomy of the facial soft tissues and teeth. Structured light patterns when combined with photogrammetry to accurately measure the light pattern result in the generation of an accurate three-dimensional map of the lighted structure.

Digital sensor technology combined with robotic imaging machines will be valuable because multiple images can be acquired quickly using precise projection geometry. Furthermore, once multiple digital images have been captured, synthesized tomographic software algorithms can create an infinite number of tomographic slices from the digital images. Instrumentarium Imaging plans to commercially introduce a variation of synthesized tomography called TACT (Tuned Aperture Computer Tomography).[4] The Instrumentarium system will use the company's OP-100 robotic panoramic unit with a CCD sensor to acquire multiple images from various angles. Ortho TACT software algorithms will compute the tomographic image layers to be displayed. This is an important advancement because it provides additional information without additional radiation, has the ability to reveal hidden anatomy, eliminates superimpositions, and provides three-dimensional data.

Anatomic Reconstructions

CT scans and magnetic resonance images are now available for three-dimensional reconstruction of anatomy, but these input devices have not been a practical solution because of their limited value and cost. Currently utilizing standard dental input devices, the clinician must mentally conceptualize the three-dimensional anatomy. Software is in development that will use multiple standard two-dimensional radiographs, photographs, and three-dimensional image sets and combine them into a three-dimensional matrix. To combine multiple image sets into a three-dimensional matrix, the image sets must be geometrically corrected to true size and accurately registered into a common spatial reference system. Once the images have been combined into a common three-dimensional matrix, anatomic structures can be defined, measured, and segmented into individual objects. Anatomic objects, such as the mandible, maxilla or teeth, can be analyzed in detail. These models can be used for diagnosis, treatment planning, treatment simulation, communication, and treatment outcomes evaluation. There are no commercial programs available to combine multiple image sets into a three-dimensional matrix. Acuscape International, Inc., (Glendora, Calif.) has software available for research purposes and is in the process of developing a commercial version (Figures 8, 9, and 10).

Dynamic Modeling

Three-dimensional dynamic modeling is emerging as a useful way to analyze structural and functional interactions. These models can be used to predict muscle, occlusal, and articular biomechanical events during simulated function and examine deviations in form and function. Dr. Alan Hannam, University of British Columbia, has developed dynamic models that can be used to analyze the interactions between form and function. Commercial models are under development by Acuscape International.

Future Role of Imaging Centers

Patient-specific three-dimensional interactive models will be a valuable aid to the general dental and specialty practices. However, model construction within individual practices will not be practical because of the time and expertise required. Model building is an ideal task to be outsourced to an imaging center. The imaging center can build the model and send it via the Internet or soft copy to the referring doctor. The referring doctor can view and interact with the model utilizing a special set of software tools designed to extract the desired information. New input devices such as three-dimensional digital cameras and TACT imaging systems will be ideal additions to an imaging center because it has the expertise to adopt the technology early and make it available to the dental community.

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Commercial Applications of Tuned Aperture Computed Tomography

Douglas Woods

ABSTRACT Tuned Aperture Computed Tomography will allow the creation of three-dimensional images of dental structures from layers of digital information that can be gathered in the dental office. These three-dimensional images will give a fuller view of the structures, thereby providing more information from which to make a better diagnosis. Unlike similar medical tomosynthetic imaging techniques, TACT should be easily accommodated into dental practice needs.

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Since Roentgen's discovery of the X-ray, imaging has involved the projection of three-dimensional objects onto a flat film or digital sensor. All structures, regardless of their height above the film, are collapsed onto that one plane, which causes superior and inferior objects to be superimposed on top of each other. Any information about their real location or shape is lost. In a maxillary molar for example, buccal and palatal roots are blended together as a single object.

The digital future should provide better imaging than is currently available. There are lines forming with people wanting to buy state-of-the-art digital technology. What they really want is more information from which to make a better diagnosis.

The next generation of digital technology will provide more information than film. This increase in information will not necessarily result from higher-resolution detectors, because the dose and file-handling needs increase disproportionately to the information. Rather, the next leap of technology will be in building a third dimension by assembling many layers of information. If one could lift off layers of superimposed information, he or she could reach the region of interest. To clean an X-ray image of ghost shadows and artifacts would be the same graphical leap as color television was from black and white. The computer box and sensor will be about the same; imaging magic will come from software.

A very helpful way to think about this change comes from a recent article by Richard Gordon, PhD.[1] He states that plane film radiology can be compared to the Where's Waldo? children's book series. In the Waldo books, one is expected to find the character Waldo on a graphically confusing page. When one considers the dentist's role to find a lesion hidden in the trabecular pattern of the mandible, one can imagine the similarities. If many pages of the book where transparent and superimposed on top of the first page that one was looking for Waldo on, it would be very difficult to find Waldo.

Dentistry could look to the medical imaging industry for an answer in tomosynthetic techniques, but these systems are not practical for dental needs. For tomosynthetic imaging, absolute lack of motion is required. Accuracy regarding projection angles for images made are required to be within tenths of degrees. Obviously, obtaining and maintaining this amount of precision in a dental practice is impractical, not to mention cost- and space-prohibitive.

One promising method to produce three-dimensional and layer imaging is called Tune Aperture Computer Tomography, or TACT. TACT was developed in conjunction with Dr. Richard Webber, a professor at Bowman Gray Medical School, and the National Institutes of Health. TACT utilizes multiple low-dose two-dimensional digital images taken from varying angles to produce three-dimensional images. The tune aperture refers to the varying viewing angles at which the two-dimensional base images are recorded. In essence, the aperture is the opening in space from which to view an object. Viewing the world through a long cardboard tube is drastically different than viewing it through a picture window. Varying the angle at which the raw data images are taken results in tuning or optimizing the size of this window for each application. The TACT algorithm computes the tomographic layers and three-dimensional reconstruction using the information from this larger point of view. A reference point is built into the charge-coupled device image sensor, which permits the PC-based software to calculate projection geometry after the exposure. This technique permits patient movement between exposures, allowing for use in a real clinical setting.

For dentistry, TACT can be used to produce three-dimensional views of teeth, pathology, the TM joint, or other areas of interest. Extremely thin layers may be produced, which allow a practitioner to step through an object layer by layer revealing internal detail. Image quality is enhanced by the rejection of overlying artifacts and mathematical reduction of noise. Webber and colleagues[2] suggest that TACT will be a great aid in diagnosing fractures of crowns and roots as well as detecting auxiliary canals. Other promising areas they foresee are in the detection and precise location of periodontal bone loss or gain, periapical lesion localization, and TM joint bony changes.

Nair and colleagues3 have shown that this technique is extremely effective in the detection of new and recurrent carries, with efficacies significantly greater than that of film or standard digital imaging, with ROC areas (Az) of 0.6608 for Ektaspeed Plus film, 0.5979 for RVG, and 0.9171 for interactively restored TACT.

Layer thickness, layer location, and numbers of layers can be selected in image post-processing. Typical layer sizes are 1 mm, but they can be smaller. The raw data can be reprocessed several years later with a new layer thickness. Other capabilities of TACT are its ability to produce a holographic-like image, which may be manipulated and viewed from different angles. The technique may be very useful when trying to understand complex anatomy, such as TM joints and alveolar bone contours. When the TM joint is viewed in this way, condylar position and osseous condition may be more clearly understood.

From a manufacturer's, as well as clinician's perspective, TACT is a natural as an add-on feature for a panoramic X-ray system. Computers in modern panoramic systems control X-ray generation and unit movements. This computer control automates the required data acquisition and provides approximately eight images from a 30-degree arch in less than 40 seconds. A patient may be placed in the panoramic unit with a digital sensor positioned at the region of interest. The operator merely needs to press the exposure button, and the system would make fractional dose exposures during the excursion. After the raw data is acquired, the TACT algorithm automatically processes them. The clinician may choose the number and location of slices and pseudoholographic images at that point or at a later session.

The marriage of these two technologies – computer controlled panoramics and TACT – should reduce costs and office space requirements. The digital sensors can provide double duty; they may be used for TACT imaging in conjunction with the panoramic system or for standard digital intraoral imaging in a dental chair.

The current commercial plan is to launch Ortho TACT as an additional option to the existing Orthopantomograph OP100 panoramic imaging system. It uses the unit's X-ray generator and drive systems to produce the required raw data images from multiple angles on a digital sensor and

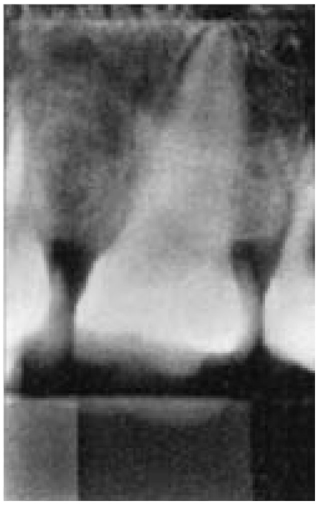

Figure 1a.

Figure 1b.

Figure 1c.

Figure 1d.

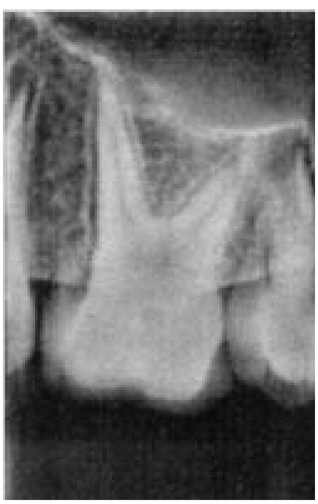

Figure 1e.

Figure 1f.

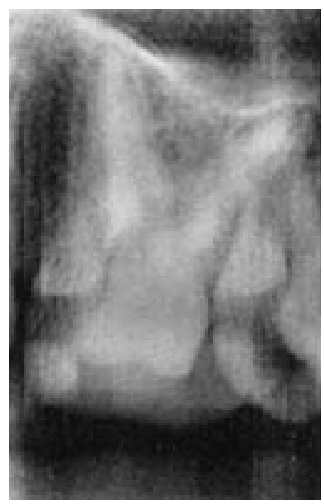

Figure 1g.

Figure 1a through g. These images show a progression of 0.75 mm vertical cuts of a maxillary molar stepping from the apex of the palatal root to buccal.

links this data to a nearby computer workstation. Digital intraoral, digital panoramic, and TACT images may be networked throughout an office and viewed chairside.

The progression of digital imaging is similar to the progression of plastic containers. Plastic containers were made to be exact copies of the glass containers they replaced, just lighter. But as time went by, the concepts of the past were abandoned and completely new packaging was invented. Today, most plastic containers do things never possible with glass. In the digital area, this is happening to dental X-ray imaging.

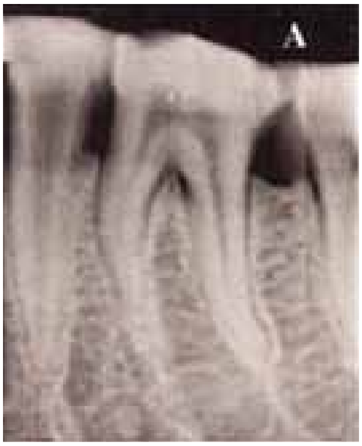

Figure 2a.

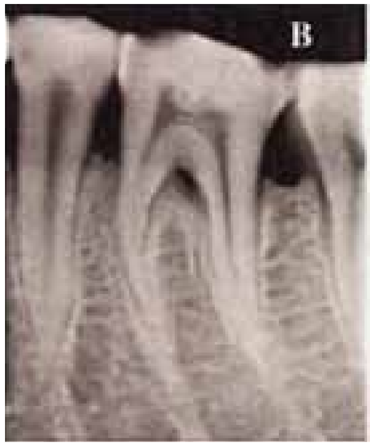

Figure 2b.

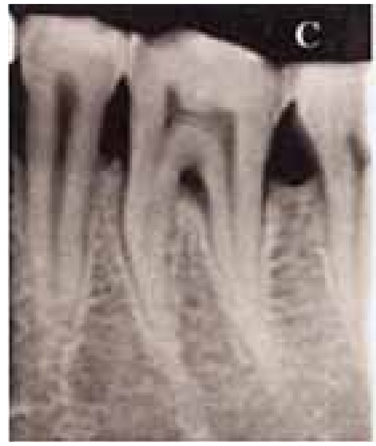

Figure 2c.

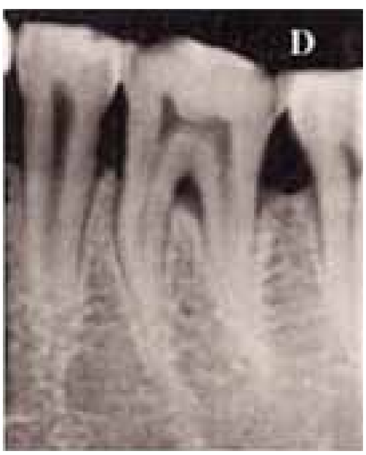

Figure 2d.

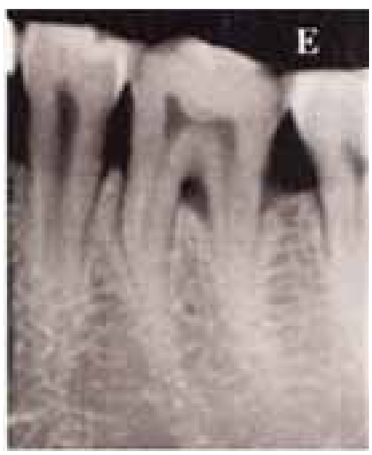

Figure 2e.

Figures 2a through e. These images show 0.75mm vertical sagittal cuts through a mandibular first molar. Note the mesial buccal canal in Figure 2a and the mesial lingual canal in Figure 2e. A fracture in the buccal cusp is also visible in Figures 2a and b.

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Digital Radiography and California Third Parties

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ABSTRACT Acceptance of digital radiography is increasing but has not yet progressed to the mainstream. A key factor in widespread use of this advancement is acceptance – both theoretical and technological – by dental health plans for claim submissions. This article details a survey of California third parties to examine their practices, concerns, and plans regarding digital dental radiography.

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Interest and acceptance of digital radiography in dentistry is undeniably on the increase. A previous issue of the *Journal of the California Dental Association*, wholly devoted to oral radiology (May 1995), featured traditional topics of quality assurance,[1] infection control practices,[2] oral pathology case diagnosis,[3,4] radiation risks and safety,[5] and "The Don'ts of Maxillofacial Radiology."[6] The only mention of digital maxillofacial radiography was found in Langlais and Langland's[5] article on radiation safety. They primarily described the reduced dose advantages of these systems but also presented general technological features and listed other advantages of digital radiography, which – at that time – was still in a period of relative infancy.

In October 1997, the Journal highlighted "Technology in Dentistry" and featured an article by Denton and Thomas[7] titled "Digital Radiographs – Will the Future Ever Arrive?" Now, this issue of the Journal is entirely devoted to the topic of digital maxillofacial radiography. Martin[8] estimates that 5 percent of dental offices faithfully incorporate some form of digital radiography into their practices.

A variety of factors are promoted and recognized as advantages of digital imaging over film-based imaging and thus are forces behind the trend. Reduced patient radiation dose; elimination of darkrooms, with their messy chemistry and hazardous waste disposal concerns; increased efficiency resulting from no delay in the production of a viewable radiographic image; promotion of the "cutting edge" image of the practice; and cost-effectiveness are some of the commonly discussed advantages of digital imaging systems. In addition, communications and interactions with third-party insurance carriers are improved by the capability of transferring digital radiographic information electronically. Farman[9] reported that "approximately 20 percent of dental services covered by third-party insurance carriers in the United States require submission of radiographs for prior approval of treatment" and that electronic submission of radiographs in digital format for preauthorization of treatment and for proof of services rendered reduces administrative costs, shortens delays in treatment and reimbursement, and eliminates the potential loss of original film-based radiographs if mailed. Martin[8] also outlined advantages of digital radiographic images related to third parties. He described digital radiographs, either printed on paper and mailed or submitted electronically, as being a fraction of the cost involved of processed film. He added, "Insiders are hopeful that as more images are submitted electronically, third-party payers will be more likely to divvy out higher reimbursements at a more expedient pace." Davis[9] believes that the advantage of electronic transfer of radiographs to insurance carriers is yet to be proven. He states: "In reality, very few, if any, insurance companies are either equipped or actively encouraging practitioners to submit (digital dental radiographs) electronically." Denton and Thomas[7] outlined several benefits of using digital radiographs in a modern dental practice but also included an analysis of insurance companies and the obstacles they face in becoming equipped to manage electronic data interchange (EDI). They believe that, "Overall, dental insurance companies have been slow to modernize their backroom operations, including EDI, in comparison to trends in many other industries."

The authors of the current article investigated the practice, attitudes, and plans of third parties with respect to digital radiography and its promises. Specifically, the purpose was to develop and distribute a survey to the 34 dental health plans registered in the state of California to determine their policies, practices, plans, and concerns related to the use of digital dental radiographs in the processing of dental insurance claims. This information may assist dentists who are seeking to understand the value of digital radiography systems as they incorporate them into their practices.

Materials and Methods

A list of 34 dental health plans, licensed by the California Department of Corporations, was obtained from the coordinator of CDA's Council on Dental Care. For each company listed, a contact person was identified. A simple survey form was developed requiring no more than 10 to 15 minutes to complete. This survey was mailed in December 1998 to each company's representative officer. If no response was received after three weeks, a telephone call or second mailing was made in an attempt to include the greatest number of health plan companies in the study.

Three categories of questions were included in the survey. The first category focused on the company's size and reliance on electronic claims processing in general. The second related to the acceptance of digital dental radiographs either in printed or electronic form and what software systems were being used to process the images. The survey also inquired about the timetable for implementation of such a system if one did not currently exist. The third category related to the company's comfort level with the integrity and quality of the information contained in radiographs in a digital format. In this category, one question was designed to determine preferences for groups who should set industry standards.

Results and Discussion

An overall response rate of 24 percent was obtained. This was much less than anticipated, and therefore the findings presented do not represent a majority of California third parties. However, certain themes emerged that are worthy of reporting and that merit watching as the digital radiographic trend continues. A summary of the following results may be found in **Table 1**.

The dental health plan companies that did respond reported a range of 4,000 to 600,000 claims processed monthly. Therefore, the data that could be collected includes companies that are relatively small and the very largest. For all claims processed, approximately one-third are received by the responding companies in electronic form. Half of the companies reported using a "clearinghouse" to facilitate the processing of claims. One of the dental health plans responding indicated that it operates a prepayment or capitation-type plan and therefore does not process claims of any kind. This underscores the fact that these types of plans are not reliant on interchange of administrative or radiographic records related to treatment and thus are not planning for the implementation of systems designed to expedite this process electronically.

None of the responding dental health plan companies currently accept electronic transfer of digital radiographic images;

however, 50 percent of the responding group indicated that they do accept printed copies of digital radiographs for processing dental claims. This seems to indicate an implicit acceptance of the use of this technology. Two companies reported that pilot programs to implement electronic reception and processing of claims containing digital radiographs would begin as early as 1999, continuing into the year 2000. These companies also reported that the number of dental offices using digital imaging is a major influence on this initiative. One source, close to the industry, identified the slow transmission times involved when sending and receiving the large volume of data contained in an electronic file of a dental radiograph as one of the major obstacles encountered in early trials involving electronic transfer. The typical graphic image of a digital radiograph requires from 250 to 2,500 kilobytes of storage memory, depending on the resolution of the sensor used to acquire the image. To transfer the largest of these images over a 56 kilobit/second modem in an uncompressed format would take nearly six minutes, assuming that the modem connection allowed maximum transfer speed. Various compression techniques reduce the size of these image files, making electronic transfers more manageable but at a loss of image content. One of the questions needing to be answered by third-party payers is how much image compression they will accept for the sake of efficiency in electronic transfer and still maintain their confidence in the diagnostic content of the image. To be efficient, the insurance company must be able to receive the radiographic information in a manner that is timely with respect to their computer systems responsible for handling the task. This problem may be alleviated in the future as broadband technologies become more widely available.

Because electronic transfer of digital dental radiographs is in the early stages of implementation, several of the survey questions were premature and could not be answered by the companies queried. However, these questions are valid for dentists who eagerly await the day when they can file a dental claim with the click of a mouse, complete with radiographic documentation, as well as for third-party payers planning to receive and process those claims. These questions include:

- Does your company differentiate between radiographic images that have been scanned from original films and those that are digitally acquired?
- Which of the following formats (JPEG, GIF, TIFF, PICT, other) for graphic image transmission does your company accept when digital dental radiographs are submitted electronically?
- What software does your company use for viewing image files containing digital radiographs?
- Does your company's claims processing personnel routinely use image enhancement features to obtain diagnostic information related to the claim when reviewing electronically submitted dental radiographs?
- Does your company have a support system, such as a contact person or hotline for dental offices to use, if problems are encountered with electronic transmission of claims or radiographic images?
- What is the difference in turn-around times for settlement of claims by your company for the following categories: paper claims with original film-based radiographs, electronic claims with hard-copy digital radiographs, and electronic claims with electronically submitted radiographs?

A seventh question, although not in the survey, should also be considered: Does your company's software system support Supplement 32 of the DICOM Standard? DICOM is an acronym for digital imaging and communications in medicine, with Supplement 32 having been recently written to cover all imaging modalities used in dentistry. Adherence to the standard permits devices manufactured by a variety of vendors to "talk to each another" more readily and therefore ensure interconnectivity. For example, until some standard prevails, there can be no guarantee that a digital X-ray system will be able to communicate with a particular dental office management software, intraoral camera system software, or dental health plan's software. Digital X-ray imaging companies are in the process of conforming to the new standard or have indicated their intended support. As third parties prepare to meet the challenge of increased electronic exchange of radiographs, they should plan to implement systems with DICOM Standard compatibility.

The survey also prematurely questioned the companies' experience with image quality, asking them to compare the image density, resolution, contrast, and diagnostic accuracy of digital radiographic images and original, film-based, radiographs. It also asked for a comparison of the same variables between digital radiographic images and film-based duplicates of original radiographs. A single company indicated that hard-copy digital radiographs were somewhat better in quality than original film radiographs. Other companies did not respond to this question. Third parties will need to develop confidence in the quality of electronic images as compared to traditional film-based images currently in use, and the parameters that control diagnostic image quality will need to be similar to that of film.

With respect to dental health plan companies' comfort level with the integrity of information contained in digital radiographs, all responding companies rated this issue as either a moderate or major concern. There was 100 percent agreement that unmodified digital files of radiographs need to be ensured by one method or another. Here again, a standard for ensuring image integrity would assist in the progress toward implementation of electronic transfer of radiographs for insurance communications. In spite of the companies' stated concern for image integrity, it could not be determined how companies who accept hard copies of digital radiographs were able to ensure the integrity of those images. When asked about dental health plan companies' preferences regarding which entity should develop industry standards for ensuring the integrity of electronically submitted dental radiographs, companies favored their own dental health plan industry (25 percent) or a consortium of groups (37 percent) over the digital radiographic equipment industry (0 percent).

TABLE 1

Summary of California Third Party Responses to Questions About Digital Dental Radiographs

Response Rate		24%
	Range of monthly claims processed by respondents. % of claims submitted electronically.	4,000-600,000 33%
Claims Information		
	Companies accepting electronic submission of digital radiographs	0%
	Companies accepting "hard copies" of digital radiographs	50%
	Companies having a moderate to major concern regarding image integrity	100%
Image Integrity Issues		
	Preferred groups developing industry standards for image integrity	
	Dental health plan industry	25%
	Digital radiographic equipment industry	0%
	Consortium of groups	37%
	No response	38%

Conclusions

Realistically, there are greater benefits to owning digital dental radiographic systems than their ability to facilitate better claims processing by electronic submission of digital radiographs. Immediate benefits include potential for reduced radiation dose to the patient, increased efficiency resulting from no delay in producing a viewable radiographic image, and promotion of the "cutting edge" image of the practice. Elimination of darkrooms with messy chemistry and hazardous waste disposal concerns will require more effort to effect, for example, when panoramic, occlusal, or other miscellaneous films still need to be processed.

Because the dental health plan industry is in the very early stages of implementing systems that will accept electronic submission of digital radiographs, this benefit will take longer to fully realize. Nevertheless, it appears that the trend is in this direction with the ultimate possible results proving to be quite exciting. With certain companies already pioneering pilot programs for processing claims accompanied by radiographs in digital form, the wait to begin may not be much longer than the time it takes for this article to appear in print. Full conversion to electronic exchange of radiographs is expected to take years to complete. For practices that have yet to acquire digital radiographic software and equipment, careful inquiry should be made regarding the manufacturer's policy with regard to software upgrades that may be required to enable proper communication with third parties. As support for the DICOM Standard is incorporated into newer generations of software, the older versions will become obsolete.

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Breath-o-Gram

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Now that National Fresh Breath Day has receded with sounding brass and tinkling cymbals into history ... whoa! ... wait a minute ... you didn't hear about this? Caught up in all your petty little distractions, were you? Well, you're in luck! In response to an overwhelming demand, the Center for Breath Disorders has promised to continue the "special service" that made its debut on National Fresh Breath Day.

We won't even ask if you're aware of the Center for Breath Disorders, but it does give us pause to realize that there are major developments breaking right, left and center, and yet there are dentists who are blissfully unaware of the excitement exploding on the dental horizon.

Here's the "special service" as explained by Dr. Jon Richter, founder of the Center for Breath Disorders: If you know of a friend, relative or colleague who has breath that, to put it discreetly, would wilt the spines off a cactus, all you have to do is e-mail or snail-mail a note to the center providing the offender's name and address. The center will tactfully contact that person, mentioning that a well-meaning busybody thought his life would be better if he had more knowledge about halitosis. That's all there is to it. Subtle, but plain enough so that any recipient with an IQ higher than cement will realize that the halitosis literature accompanying the note is trying to tell him something.

To get the olfactory relief ball rolling, simply dispatch an e-mail to drbreath1@aol.com and the whole thing will be held in strictest confidence. Your candidate will never know who ratted him out.

The point is, halitosis has escalated from a social boo-boo into the realm of Big Business. *The Journal of the American Dental Association* says that as many as 85 million Americans suffer from the problem. How it arrived at this figure is open to question, but obviously the heartbreak of psoriasis is small potatoes compared with the consequences of breath that would make a camel reel.

Check out any issue of the nationally distributed Dental Products Report. A full-page ad sponsored by Breath Remedy touting its In-Office Breath Center notes that 40 million suffer from halitosis.

The ADA and Breath Remedy statistics seem to be at variance but may be explained by differences in their concept of "suffer." The ADA feels that the bearer of bad breath arguably suffers as much or more than the adjacent inhalers. Breath Remedy realizes that exhalers often have no idea that they are offending, and the suffering in that case is unilateral.

The company is offering a device called the Halimeter as the standard dental office tool for detecting and determining the extent of the problem. Instead of a .08 reading sending you off to the pokey as with the more familiar police Breathalyzer, you are directed to the In-Office Breath Center. There, sympathetic personnel will assure you that in less time than it took to consume an entire Pizza Supreme with extra garlic anchovies, you can return to the social whirl.

Discus Dental is right in the forefront with its BreathRx, an attractive countertop merchandiser replete with tongue scrapers, assorted pills to neutralize those volatile sulfur compounds, and a neat little display they call a "Product Glorifier," a sort of respiratory makeover kit.

In the same issue, Rowpar Pharmaceuticals, Inc., is proud to announce the availability of a line of products designed "for everyone you want to get closest to." If you can't overwhelm them by the sheer force of your personality, this array of toothpaste, mouth rinses and compact oral sprays should at least get you a slot somewhere near the front of the line.

Listen to the words of Roger P. Levin, DDS, MBA, president of the Levin Group: "Today, we must look at all possible avenues of dental productivity and expansion. In looking at the future of dentistry, I predict that most practices will carry and sell dental-related products."

I think we can all go along with Roger on this one. Obviously, if one is to fulfill his mission as a health care provider (formerly known as "dentist"), one is going to focus a little more shrewdly on what priorities are most likely to impress one's accountant.

Why we have been so lax in this department is a puzzlement. Looking back in the dental literature and advertising of 20 years ago, references to bad breath and its deleterious effect on the nation's social structure and the ensuing depletion of the ozone layer are conspicuously absent.

What then, has exacerbated the problem to the point of requiring dental publications to devote hundreds of column inches expatiating on the crisis? We may surmise it is the increased consumption of chili cheese burritos or perhaps a consumer rebellion against tedious exhortations by dentists to floss more often, but we suspect it has more to do with the fact that somebody discovered we are supporting a $4 billion-a-year business in breath disorder products and treatments.

Dr. Louis Jay Malcmacher, a Cleveland dentist and international lecturer on a number of topics, including breath disorders, estimates that bad-breath treatment fees can hover somewhere between $550 and $700. Insurance companies that are still having problems with covering porcelain veneers have promised to look into the matter of halitosis treatment benefits sometime toward the end of the new millennium.

Not a problem, avers Dr. Malcmacher, "We have the patient pay our office in full before treatment begins. With these bad-breath cases, money is generally not an issue; most patients have gladly paid for an effective treatment of their halitosis problem."

Don't for a minute imagine this whole phenomenon is not being closely scrutinized by other health professionals. The American Podiatric Medical Association, for example, is keeping an eagle eye on the success of dentists. Its lukewarm in-office merchandising of Odor-Eaters and Dr. Scholl's Foot Powder has languished far short of the $4 billion windfall accruing to dentists. Before long, you can look for a friendly anonymous suggestion in the mail that your feet could perhaps benefit by some advanced scientific knowledge judiciously applied in a conscientious effort to enhance not only your life, but those of the persons near and perhaps dear to you. Nike, Reebok, Converse and Keds have gone into Full Red Alert Merchandising mode. Can Gas-X and Arrid be far behind?