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Applying DICOM to Dentistry

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There are more than 160,000 dentists licensed in the United States. For the dental patient, the dentist is both radiologist and treating clinician. The American Dental Association (ADA) has been a member of the Digital Imaging and Communication in Medicine (DI-COM) Standard Committee since 1996. DICOM v.3 provides image object definitions for digital transmission radiography (Dx) with special categorization for intraoral projections (Io), and it also provides for color photography used in dentistry. Digital dental radiographs include transmission images of the head and jaws, pantomography, tomography and cone-beam computed tomography. In 2000, the ADA resolved to strive for interoperability of digital dental images, using the DICOM Standard as the backbone of the effort. ADA Working Group 12.1 was tasked with development of specifications and also with educating the dental profession concerning digital image interoperability. DICOM-related interoperability demonstrations are now a part of the ADA Annual Congress, in the form of seminar and as a noncommercial exhibit.

KEY WORDS: Dentistry, DICOM, digital imaging, interoperability, radiology, dental, radiology, oral and maxillofacial

THERE ARE MORE than 160,000 dentists in the United States, most working in relatively small private practices rather than in hospital circumstances. Each of these dental practices is equipped with radiography equipment, and in the practice of dentistry they expose approximately 400 million intraoral x-ray images in addition to panoramic and other extraoral projections. In addition to radiographic images, dentists often make photographic and video records, and optical impressions are occasionally made for computer-aided design and fabrication systems used to manufacture dental restorations. Hence, dental practices generate many diagnostic images and can

benefit from application of the Digital Imaging and Communication in Medicine (DICOM) Standard as a means of promoting system interoperability.[1,2]

It is possible to view analog radiographs or photographic prints that are decades old. All one needs is a view box for the former or adequate ambient lighting for the latter. Computerization is making inroads into the way the practice of dentistry is conducted, evermore frequently including the digital acquisition and display of radiographic and video images. With the rapid progress in computer design and platforms, it is reasonable to question whether it will be possible, decades from now, to read diagnostic images made using current digital systems. Even now, it is often not possible to read images made using one proprietary system with another vendor's display software. This may well be the reason that full implementation of the "filmless" dental office has lagged behind expectations. All too frequently, vendors have used proprietary file formats that restrict the reading of diagnostic images to their own display software, and even different generations of a given manufacturer's imaging system have demonstrated incompatibility. To protect the user's investment in equipment and the patient's investment of in time, money, and radiation

Fig 1. Examples of image communication needs in dentistry.

exposure, it is desirable to specify a standard that will make digital radiographic images at least as durable, in terms of access for use, as their silver halide predecessors. It is with this in mind that a project with American Dental Association (ADA) sponsorship is under way to develop and demonstrate interoperability of digital images. This activity is based on the DICOM Standard. It must be noted from the outset that even though adhering to DICOM standards can help remove the uncertainty of file format issues, it is not a guarantee against physical media obsolescence or degradation. Digital images need to be stored on durable media and regularly transferred between updated media.

REVIEW

The ·DICOM standard was first adopted conceptually in the early 1980 s by joint activity of the American College of Radiology (ACR)

and the National Electronics Manufacturers' Association (NEMA).[3] A number of other groups such as the American College of Cardiology and the American Dental Association have since joined the effort. The DICOM Standard is a set of rules for communication of images and related materials, its adoption is voluntary, and it is international in scope. It provides a detailed specification for formatting and exchanging images and associated information. This Standard is applicable to all imaging, including radiographs and photographs used in dentistry. DICOM has been adopted as a worldwide standard by such bodies as the European Committee for Normalization (CEN TC 251) for the European Standard MEDICOM. The Japanese Industry Association for Radiation Apparatus (JIRA) standard, MIPS, is also based on DICOM.[4]

In the hospital setting, patient diagnostic images can include computed tomograms, magnetic resonance images, nuclear medicine
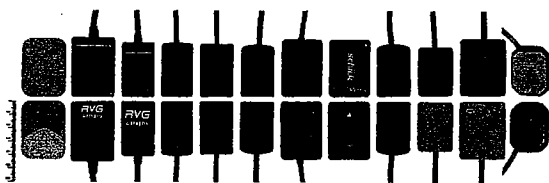
Fig 2. Analog x-ray film and some of the many solid-state detectors currently marketed for intraoral radiography. Top row shows front of detector and lower row shows rear. From left to right, the detectors illustrated are: size 2 InSight analog intraoral x-ray film (Eastman Kodak, Rochester, NY), RVG-ui size 2 detector (Kodak, Marne-la-Vallée, France), RVG-ui size 1 detector, size 1 Planmeca detector (Planmeca Oy, Helsinki, Finland), Owandy DSX730 detector (Owandy/Julie Radio Vision, Gragny, France), Visualix HDI (Dentsply/Gendex, Des Plaines, Illinois), size 2 CDR (Schick Technologies, Long Island City, New York), size 2 CDR wireless, RSV (Visiodent, St. Denis, France), size 1 CygnusRay Progeny/ Cygnus Technologies, Scottsdale, Arizona), size 2 Cygnus-Ray, and Dexis (Provision Dental Supplies, Atlanta, Georgia).

Fig 3. The Dentsply/Gendex DenOptix (Des Plaines, Illinois) is one of several currently marketed storage phosphor scanning systems used in dentistry for intraoral, panoramic and cephalometric radiography.

scans, ultrasound, and more recently flat panel displays of regular transmission radiographs. DICOM was originally developed to permit the convenient reading of images from different digital imaging devices; it is the accepted standard in medicine, with DICOM conformant being commonplace.

Dentists, however, primarily work in small practices and, unlike their physician counterparts, usually make most of the diagnostic images for their patients on site. Nevertheless, dentists sometimes refer patients to various specialists for second opinions or provision of certain advanced procedures (Fig. 1). Referring an analog radiograph to a consulting specialist is a simple matter, as anyone with a view box can "interoperate" with the provided image. Without interoperability standards, however, digital image communication is unlikely, especially when two practitioners use divergent imaging software. The same problem can also be encountered within a single office given use of digital image acquisition systems from different vendors—or even just different generations of detectors or software from a single vendor. Manufacturers of digital dental imaging equipment are only now seeking to become DICOM conformant. With the continual introduction of many new CCD (charge-coupled device) and CMOS (complementary metal oxide semiconductor) solid-state, and storage phosphor x-ray image detectors (Fig. 2 and 3), a
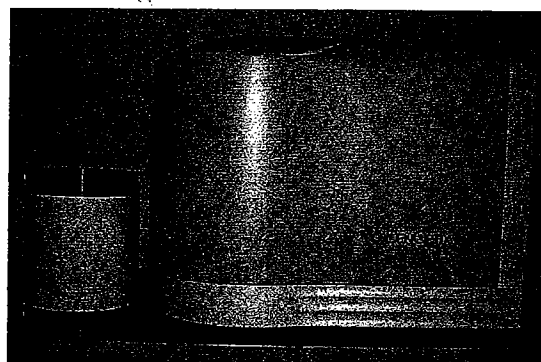
standard for exchange is becoming ever more important for the reading of dental diagnostic images. Such exchange is needed to protect the usefulness of acquired diagnostic information, thereby providing patient data integrity and accessibility. Image interoperability also protects the dentist's investment in digital equipment and permits later migration to alternative systems. Is DICOM necessary for interoperability? The answer to this question is no. However, as the DICOM Standard has been developed it would seem unreasonable to reinvent the wheel by introducing a separate standard for digital dental products.

The ADA became a member of the DICOM Standards Committee in 1996. In 1998, the digital x-ray supplement to the DICOM Standard was approved, and this is applicable to transmission radiographs, including those used in dentistry. In 1999, the visible light supplement to the DICOM Standard was approved, and this is applicable to video, endoscopic, and microscopic images used in dentistry and the dental specialties. In July 2000, vendors present at the International Congress and Exposition on Computed Maxillofacial Imaging (CMI) held in conjunction with the 14th Computer Assisted Radiology and Surgery Congress in San Francisco, set a goal of demonstrating digital image format interoperability. The CMI initiative was industry initiated, focused on taking small practical steps, and set the first goal to be DICOM image export and reading capability using each vendor's system. Mean-

while, in October 2000, a working committee of the ADA suggested DICOM implementation for the communication of images in dentistry. This recommendation was taken to the Information Technology Committee of the ADA, and on November 10, 2000, the ADA Board resolved to implement DICOM as the standard for transmitting digital dental images.

B-164. Resolved, that the ADA adopt the Digital Imaging and Communication Standard (DICOM) as its standard for communication of digital dental images; and be it further Resolved, that the appropriate agencies of the ADA develop and communicate a definition of compliance with the DICOM and other relevant standards that can be used by the members to ensure vendor's compliance and be it further Resolved, that the appropriate agencies of the ADA develop a mechanism for recognizing vendors in compliance with the ADA definition of the DICOM and other appropriate standards.

B-165. Resolved, that the appropriate agencies of the ADA be urged to incorporate participating DICOM vendor demonstrations as part of the ADA Annual Session, and be it further Resolved, that these vendor demonstrations provide the member a comparison of interoperability of imaging across different practice management systems, and be it further Resolved, that the appropriate agencies of the ADA assist other regional meetings to incorporate participating DICOM vendor demonstrations in their meetings.

American Dental Association WG 12.1 was charged with bringing the requirements of resolutions to fruition. At the time, vendors of digital imaging systems for dentistry were not following uniform implementation of the DICOM Standard, if they were following DICOM at all. Moreover, in many instances, information that is critical to identify a patient or a study was entirely missing or was encoded in fields other than the header. To resolve this situation, it was necessary to establish a set of DICOM interoperability goals for imaging equipment. These goals required that modality vendors follow a common specification based on the DICOM Standard to properly communicate critical patient and study information. Such a specification is presently under development. Many of the core dental requirements

directed toward the independent private practitioner that have been specified by ADA WG 12.1 concern the ability to read and write valid DICOM data sets to removable media and can be expressed as a media application profile. These include the following:

1. DICOM image file format will be the standard for exchange of grayscale radiographic images.
2. For-presentation images will be supported. For-processing image support will be optional.
3. Removable media (eg, general purpose CD-R and DVD-R) will be supported to point exchange of grayscale radiographic images.
4. The DICOMDIR will be supported. In line with the DICOM Standard, a standard file extension will not be used.
5. Uncompressed DICOM and DICOM specified JPEG lossless compression will be supported. These elements are embedded in the proposal for American Dental Association SCDI WG 12.1 Technical Report 1023.

It is understood that as many of the dental conformance requirements as possible should be rolled into the DICOM Standard itself, using the DICOM conformance mechanisms that already exist. Moreover, for complex situations requiring networking, as is the case for hospital dentistry, it will probably be necessary to follow an Integrating the Healthcare Enterprise (IHE) Technical Framework such as that adopted by the Veterans Administration Modality Requirement.

Regarding the issue of educating the dental profession about the meaning of DICOM and the need for interoperability of digital imaging systems, a technology seminar was initiated at the ADA Annual Session in New Orleans in 2003. At this half-day workshop, ten vendors of digital imaging systems participated to demonstrate the advantages of using the DICOM Standard to allow interoperability of images. Various scenarios were acted out. These scenarios included exchange of images for referral and second opinion, both to individual practices and to hospital clinics, and transfer of data following patient changing place of residence. The pitfalls of using non-DICOM and secondary capture images were also demonstrated.

The educational aspects of the dental DI-COM initiative were repeated at the 2004 ADA Annual Congress in San Francisco. The ADA interoperability workshop was augmented in 2004 by the addition of a noncommercial booth throughout the Congress. The demonstrations at this area of the Congress Exhibit are intended to be similar in format to infoRAD and IHE activities conducted at Annual Meetings of the Radiological Society of North America.

Late in 2003, a new DICOM Working Group was initiated; namely, WG 22 (Dentistry). This DICOM WG holds joint meetings with ADA SCDI WG 12.1 under common Co-Chairs and has essentially the same membership. The ADA acts as secretariat for DICOM WG 22. The aim of DICOM WG 22 is to develop new aspects of the DICOM Standard per se, whereas ADA SCDI WG 12.1 has the broader goal of achieving and demonstrating interoperability. In 2004, DICOM WG 22 was responsible for producing DICOM Supplement 92, Media Application Profile for Digital Radiographic Images in Dentistry.

DISCUSSION

DICOM conformance does not guarantee system interoperability. Perhaps no written statement could ever do so. Conformance statements are meant for comparison; without a written document there could be no conformance with DICOM. The final test for interoperability will always be demonstration; hence, the introduction of such activities at the Annual Congress of the ADA.

Image format and attribute interoperability should give comfort to the users of digital diagnostic equipment, and to their patients, in that images acquired on equipment purchased today should still be viewable into the future, and that upgrades to newer equipment will not automatically mean loss of important diagnostic information. Furthermore, diagnostic images should be portable to other professionals who may have digital imaging equipment from a different vendor. For the dental imaging industry, interoperability would seem to be a logical selling point. In seeking to retain proprietary controls over image formats, dental imaging vendors have previously done themselves no favors in the marketplace.

SUMMARY

The DICOM Standard is a set of international imaging standards developed for medicine and now extended to incorporate other professions. These standards encompass primary digital and secondary capture images made for dental diagnostic procedures. DICOM provides a basis for the interoperability of digital systems' outputs, providing portability and reducing the danger of obsolescence that could otherwise render diagnostic information impossible to display. The American Dental Association, through activities of its Working Group 12.1, is promoting interoperability within DICOM as the industry standard for digital imaging in dentistry.

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