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Use and implication of the DICOM standard in dentistry

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It is not unusual to review film radiographs that are decades old, especially when demonstrating "classic" radiographic features of disease entities to a class of dental students. Archived film images that are decades old are usually still of high quality and can be viewed by anyone who happens to have a view box to transmit light through the radiographs. Such images are currently being scanned carefully into PowerPoint presentations as one depends more on computer-based presentations. One might question whether the digitized versions will be as readily accessible as the analog film versions decades into the future?

Computers also are making inroads into the way we conduct dental practice, including digital acquisition and display of radiographic and video images. With the rapid progress in computer design and platforms, one again can question whether it will be possible in the future to read diagnostic images made using current digital systems. Even at the same point in time, it is often not possible to read images taken using one proprietary system when using another vendor's display software. Could this be the reason that full implementation of the "filmless" dental office has lagged behind expectations?

Frequently, vendors use proprietary file formats that restrict the reading of diagnostic images to their own display software, and even different generations of the same manufacturer's imaging system have demonstrated incompatibility. To protect the user's investment in equipment and the patient's investment in time, fees, and radiation exposure, it is desirable to define 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 goal in mind that a project with American Dental Association

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sponsorship that seeks to develop and demonstrate interoperability of digital images is currently under way. This activity is based on the international DICOM standard. It must be noted from the outset that although the DICOM standard can help remove the uncertainly of file format issues, it is not a guarantee against physical media obsolescence or degradation. Images still must be stored on durable media and transferred between updated media regularly.

What is DICOM?

The acronym "DICOM" stands for *d*igital *i*maging and *c*ommunication in *m*edicine and was first adopted conceptually in the early 1980s by joint activity of the American College of Radiology and the National Electronics Manufacturers' Association [1]. Several other groups, such as the American College of Cardiology and the American Dental Association, have since joined the effort. DICOM is a standard for communication of images and related information between devices and is a voluntary standard that has become international in scope. It provides a detailed specification for formatting and exchanging images and associated information. This standard is applicable to all imaging media, 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, also is based on DICOM [2].

Why DICOM?

In hospital situations, patient diagnostic images can include CT scans, MRI, nuclear medicine scans, ultrasound, and, more recently, flat panel displays of regular transmission radiographs. DICOM was developed to permit the reading of images from different digital imaging devices on the same monitor. DICOM is the accepted standard in medicine, with nearly 100% of medical imaging systems being DICOM conformant.

Unlike medicine, vendors of digital dental imaging equipment are only recently seeking to become DICOM conformant. With the introduction of solid state and photostimulable phosphor x-ray image detectors and digital video photography, a standard is also needed for exchange of images among different dental practitioners. Such exchange is needed to protect the usefulness of acquired diagnostic information and provide patient data integrity and accessibility. Security and accessibility of diagnostic information are required in the recently implemented United States Health Insurance Portability and Accountability Act (HIPAA) regulations. Using the DICOM standard, images also could be forwarded to a clearinghouse or third party insurance carrier for prior approvals of treatment or proof of treatment

rendered. Image interoperability protects the dentist's investment in digital equipment and permits later migration to alternative systems.

By selecting identical entries for DICOM required fields—in effect "slimming" the DICOM— it is possible to increase the likelihood of interoperability as far as reading images and their file attributes designating such vital information as the patient's identity. This is perceived as advantageous to the patient, the users, and vendors of digital systems. The concept of interoperability within the DICOM can be considered analogous to the universality of faxed information from fax machines made by different vendors. Although vendors still compete on product design features, the transmitted information is translatable by all fax machines. This is the concept of interoperability that is desirable for digital diagnostic images produced by dentists.

Is DICOM necessary for interoperability? The answer to this question is no. As the DICOM standard has been developed, however, it seems less than sensible to reinvent the wheel by introducing a separate standard for digital dental products. This is particularly the case when DICOM conformance is a purchase requirement for all radiography systems purchased by such entities as the United States Military and Veterans' Administration. From a vendor perspective, having only one standard to fulfill is obviously the best situation.

DICOM in perspective

In the early 1980s, the American College of Radiology (ACR) and the National Electronics Manufacturers Association (NEMA) set the goal of interoperability of images made using equipment from different vendors [1]. The ACR-NEMA standard version 1 was released in 1985 and conceived a physical linkage between systems involving a 50-pin connector to be key to success. The ACR-NEMA standard version 2 was released in 1988; however, acceptance and implementation of the ACR-NEMA concept was slow until the concept evolved from physical linkages to software solutions with the development of DICOM version 3 starting in 1992. With DICOM version 3.0, the DICOM concept moved from a unique 50-pin connection to use of networks based on transmission control protocol/Internet protocol (TCP/IP) and open system interconnection (OSI) [International Standards Organization (ISO)]. (Note: Transmission control protocol divides data units into sequences of packets at the transmission end and reassembles them at receiving end. The Open system interconnection was developed by the International Standards Organization.) DICOM version 3.0 feasibility was demonstrated by 25 vendors during the *info*Rad exhibit of the Radiological Society of North America Annual Scientific Session in November, 1994 [3].

The DICOM standard is broad and the latest version can support the following specialties:

- Intraoral radiography
- Panoramic radiography

- Cephalometric radiography
- Tomography
- Skull and sinus radiography
- CT, ultrasonography, MRI, poitron emission tomography, and nuclear medicine
- Intraoral cameras and endoscopy
- Microscopy (surgical and histologic)
- Wave-form representations (eg, electrocardiogram and electroencephalogram)

The DICOM committee is composed of member organizations rather than individuals, with most of the organizations being manufacturers. It is supported by several active working groups. The committee itself meets four times a year to conduct business. DICOM is an organic document that provides for continual updates and improvements.

The DICOM standard currently comprises 13 parts [2]. Part 1 provides the introduction and overview. Part 2 concerns conformance. This part specifies the general requirements to be met to claim conformance and details the components of the conformance statement. Part 3 covers information object definitions, including patients, images, and studies. Part 4 covers service classes and defines operations that can be performed on information objects (eg, patients, images, and studies). Part 5 concerns data structure and semantics and specifies the encoding of the data content of messages exchanged in operations used by services classes. Part 6 involves the data dictionary and defines the information attributes that represent the data contained in information objects. Part 7 concerns the protocols used to exchange messages. Part 8 defines network communication for message exchange on OSI and TCP/IP networks. Part 9 details support of point-to-point communication for message exchange (including the currently obsolete DICOM version 1, 50-pin interface). Part 10 defines the file formats for storing DICOM information on different media. Part 11 covers application profiles, namely, the specification of media selection and of information objects. Part 12 concerns media formats and physical media for data exchange. Part 13 involves print management point-to-point communication support. Although each of these parts is interrelated with the rest, all parts are independent documents. There are currently more than 60 supplements to the standard, which is is continually being updated.

DICOM conformance

At the heart of DICOM conformance is the conformance statement. There cannot be DICOM conformance without this. The statement must be in writing. It specifies which DICOM components are supported, how the product conforms to the standard, and the functionality and constituent components of application entities. It is a formal compilation of the exact

set of DICOM functions, services, and options that are included in a particular implementation [4]. The conformance statement provides a comprehensive description of implementation and information on how real-world activities relate to the supported DICOM functions. This information is generally accompanied by a data-flow diagram. The statement presents the implementation model, including the presentation context (real-world activity), association acceptance policies, service object pair classes supported, communications profiles (eg, OSI stack—TCP/IP), and lists of any extensions, specializations, and privatizations (eg, private transfer syntax, extended character sets).

DICOM in dentistry

The American Dental Association (ADA) became a member of DICOM Standards Committee in 1996. In 1998, the digital radiograph supplement to the DICOM standard was approved, which applies to transmission radiographs, including those used in dentistry. In 1999, the visible light supplement to the DICOM standard was approved, which applies to video, endoscopic, and microscopic images used in dentistry and the dental specialties.

A demonstration archive using DICOM for dental applications was initiated by Dove at the University of Texas Health Sciences Center in San Antonio (1999–2000) in conjunction with Lead Tools/Medicor (Charlotte, NC). The central test node he established (http://dicomctn.uthscsa.edu) is accessible 24 hours a day, 7 days a week. This site is available to test DICOM conformance.

In July 2000, vendors that were present at the International Congress and Exposition on Computed Maxillofacial Imaging held in conjunction with the 14th Computer Assisted Radiology and Surgery Congress in San Francisco set a goal of demonstrating digital image format interoperability by February 2001. The computed maxillofacial imaging initiative was industry initiated, focused on taking small practical steps, and set the first goal to be DICOM image export and reading capable using each vendor's system. It specifically excluded driving sensors from other vendors. A deadline of February 2001 was set for this initial interoperability demonstration. It was anticipated that future steps would follow and might involve image file attribute standardization and issues of image compression.

Meanwhile, 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 Council encouraged vendors to implement DICOM as the standard for transmitting digital dental images. After presentations were made to working groups, the Committee on Interoperability, and the Information Technology Committee, the ADA passed the following resolutions during the ADA December board meeting.

Resolution B-164

Resolved, that the ADA adopt 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.

Resolution 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.

The next step: practical demonstrations

Currently, vendors of digital imaging systems for dentistry are not following a uniform implementation of the DICOM standard. In many instances, information that is critical to identifying a patient or a study is entirely missing or encoded in fields other than the header. To resolve this situation, it is necessary to establish a set of DICOM interoperability goals for imaging equipment. These goals require that modality vendors follow a common core subset of the DICOM specifications that properly communicate critical patient and study information. It is intended that this document will evolve into the definitive requirement specification used by all vendors of dental digital imaging equipment.

Images stated to be of DICOM format were submitted by Dexis (Atlanta, GA), Dentsply/Gendex (Des Plaines, IL), Planmeca (Helsinki, Finland), and Trophy (Marne-la-Vallée, France) in advance of a February 21, 2001 meeting held at the Ritz Carlton Hotel, Chicago. This was an ADA-sponsored open meeting to evaluate the results of the computed maxillofacial imaging initiative concerning image interoperability within DICOM. Although DICOM image formats were achieved, auxiliary issues, such as image attributes (eg, identifiers), left questions of DICOM conformance to be answered by all concerned. Most of the DICOM format images demonstrated were not fully DICOM conformant because the files did not have a valid DICOM

directory extension (DICOMDIR). The DICOMDIR is the directory service that is required for compliance with the Media Storage Service Class of the DICOM standard.

The path ahead: interoperability within a streamlined DICOM

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 is always demonstration. The consensus of all persons present at the February 21, 2001 meeting was that users would be well served by industry seeking interoperability within DICOM 2000 conformance. The first, and perhaps easiest, step would be for all persons interested in the process to develop the means of exporting DICOM format images. The issue then to be addressed would be to work line by line through the required DICOM fields of a conformance statement to attempt a uniform model to cover such issues as image attributes for identification and description. This would be, by necessity, a "lowest common denominator" approach that would not infringe on vendors' proprietary additions, providing that these did not interfere with the goal of interoperability. Database interoperability would be the job of practice management software vendors, because the route to retrieval of incorporated or bridged digital images would be via the practice management database in most instances.

Image format and attribute interoperability should give comfort to the users of digital diagnostic equipment and to their patients in that images acquired on newly purchased equipment should still be viewable decades into the future and that upgrades to newer equipment will not mean loss of important baseline diagnostic data. Diagnostic images should be portable to other professionals who have equipment from a different vendor. For the dental imaging industry, interoperability would seem to be a logical selling point comparable to fax technology. How many customers would buy a fax that could not receive transmissions from any fax machine other than the same brand? In seeking to retain proprietary controls over image formats, dental imaging vendors have previously done themselves no favors in the marketplace.

Actions approved

The initial drive to narrow DICOM to increase the probability of interoperability is to focus on digital intraoral radiography and digital extraoral radiography. It also includes secondary capture of radiographic images. DICOM issues related to visible light systems will be addressed at a later time.

A dental DICOM conformance statement based on Part 2 of the DICOM should become standard for all vendors. This would make it easier for

vendors, implementers, and users to evaluate and compare different vendors' products and how they may be integrated. The proposed template would be circulated to participants. After review and acceptance, the industry would respond. The aim is to achieve consensus for each of the specified required DICOM fields. The integration of any device into a system of interconnected devices goes beyond the scope of the DICOM standard. To ensure the interoperability between equipment, the next step is to create a set of validation tests.

Participation

By July 30, 2001, the following participating groups, listed in alphabetical order, were actively involved in the interoperability project:

- Air Techniques (USA)
- American Academy of Oral and Maxillofacial Radiology (USA)
- American Dental Association (USA)
- CIEOS Digital Infrastructures (USA)
- Cygnus Technologies (USA)
- DentalEye (Sweden)
- Dental Manufacturers of America (Electronic Environment Committee) (USA)
- Dental Medical Diagnostic Systems (USA)
- Dentsply/Gendex (USA)
- Dent-X AFP (USA)
- Dentrix (USA)
- Dexis Digital X-Ray (Germany/USA)
- DICOM Imaging Corporation (USA)
- Difoti (USA)
- Digident/Orex (Israel)
- Eastman Kodak (USA)
- Henry Schein Corporation (USA)
- Instrumentarium Imaging (Finland)
- J. Morita Corporation (Japan)
- Kavo (Germany)
- Konika Corporation (Japan)
- Medicor Imaging/Link Technologies (USA)
- Merge Technologies, Incorporated (USA)
- Panoramic Corporation (USA)
- Planmeca Oy (Finland)
- Schick Technologies (USA)
- Sirona AG (Germany)
- Soredex Corporation (Finland)
- Trophy Radiology (France)
- Tygerview (USA)
- Video Dental Concepts (USA)

The international DICOM Committee is fully aware of, and is pleased with, the ongoing process for applying the DICOM to dentistry. DICOM Working Group 6 was given the task of examining the anticipated results for technical acceptability and general comments during the DICOM Committee meeting held in Berlin, Germany on June 27, 2001—a meeting at which the ADA was represented by the author of this article.

The current exercise is restricted to providing interoperability within DICOM for image format for exportation, importation, and reading and for required image file attributes or identifiers. These required fields are patient's name, date of birth, patient unique identifier, study date, study time, accession number, study identifier, study instance unique identifier, study date, modality, series number, series unique identifier, a unique instance number, and the service object pair instance unique identifier. DICOM conformance for areas other than these, although desirable, is not the point of the study. Fields critical to interoperability are the essence of the activity.

In medicine the interoperability of systems was demonstrated through *info*RAD exhibits at the annual sessions of the Radiological Society of North America starting in 1992 [1]. At the time of writing, an exhibit of dental image interoperability has been accepted for presentation as part of the Radiological Society of North America *info*RAD exhibit in November 2001 [5]. Plans are in place to initiate dental DICOM and interoperability demonstrations at the American Dental Association Congresses commencing October 19–23, 2002 in New Orleans. It is only by practical demonstration that interoperability can be ascertained.

References

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