Enterprise-wide Implementation of Digital Radiography in Oral and Maxillofacial Imaging: The University of Florida Dentistry System

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The implementation of digital radiography in dentistry in a large healthcare enterprise setting is discussed. A distinct need for a dedicated dental picture archiving and communication systems (PACS) exists for seamless integration of different vendor products across the system. Complex issues are contended with as each clinical department migrated to a digital environment with unique needs and workflow patterns. The University of Florida has had a dental PACS installed over 2 years ago. This paper describes the process of conversion from film-based imaging from the planning stages through clinical implementation. Dentistry poses many unique challenges as it strives to achieve better integration with systems primarily designed for imaging; however, the technical requirements for high-resolution image capture in dentistry far exceed those in medicine, as most routine dental diagnostic tasks are challenging. The significance of specification, evaluation, vendor selection, installation, trial runs, training, and phased clinical implementation is emphasized.

KEY WORDS: Computed radiography, digital radiography, PACS implementation, tomography, x-ray computed, Digital Imaging and Communications In Medicine (DICOM)

BACKGROUND

Numerous reports have been published in the literature describing the implementation of digital radiography in the medical setting within small and large hospital systems.^{1,2} Picture archiving and communication systems (PACS) are used in such settings to enable the integration of different imaging units and vendor products so as to ensure the ease of image communication, archiving, and retrieval without loss of data. The Digital Imaging and Communications in Medicine (DICOM) standard, developed by the National Electrical

Manufacturers Association (NEMA), facilitates the distribution and viewing of radiographs and other images. The standard has been recently modified to develop specifications for use in clinical areas such as ophthalmology, dermatology, and dentistry that have unique needs. In dentistry, provision for the acquisition and display of both intraoral and extraoral radiographs, as well as color photographs, and advanced imaging modalities has been made. Film-based conventional radiographic imaging modalities are commonly used in dentistry, as per the last Nationwide Evaluation of X-ray Trends (NEXT) survey.³ However, the adoption of digital imaging is taking place at a dizzying pace with the development of the DICOM standard for dentistry. Rapid strides in the development and implementation of digital radiographic techniques have been

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Online publication 3 September 2008

doi: 10.1007/s10278-008-9149-5

made in private dental office settings as well as in large healthcare settings. However, the implementation of digital radiography in dentistry is very different from that in medicine in that most dental offices acquire radiographs chair-side and the dentist interprets the images. Until recently, images acquired using proprietary software could not be viewed in other programs without some data loss, thus making teleconsultation difficult. Modification and adaptation of the DICOM standard for use in dentistry has since effectively addressed this issue. Limitations with image generation and transmission may very well have been reasons for the late adoption of digital radiography by the dental community. Specialty practices are spearheading this transition to filmless radiography. However, in hospital settings which are digital, it is imperative that a department of dentistry comes on board with filmless radiography. However, the implementation of digital radiography and integration of multiple vendor products in a larger clinical and academic dental setting such as the University of Florida dental healthcare system is far more challenging compared to a department of dentistry within a hospital or a private dental office. Such an extensive implementation of digital radiography in dentistry is probably the first of its kind in the United States.

METHODS

The introduction of digital radiography was part of a process to set up a teledentistry network for the residents of Florida. In 2004, the University of Florida College of Dentistry (UFCD) undertook a 2-year teledentistry project to improve access to oral health care for Florida residents. Florida's overall rating for the 2003 Oral Health America National Grading Project was a C with poor or failing grades in sealant programs, prevention, and the number of Medicaid dental providers. The UFCD Statewide Network for Community Oral Health serves as a safety net for many of these low-income Floridians. All of the UFCD clinics are located in dentally underserved communities. The teledentistry project involved the use of telecommunications (computers and the internet) in dentistry, resulting in exchange of clinical information, radiographic, and other patient images over long distances, in an effort to address the problems identified in the report. To meet the

challenge of reaching this large underserved population, the teledentistry project included three goals: (1) expansion and evaluation of videoconferencing (VC) capabilities from the University of Florida Gainesville campus to health facilities located throughout the state; (2) development and evaluation of web-based educational materials for dental students, dental residents, faculty, and practitioners; and (3) development and evaluation of clinical consultation services using digital radiography for the efficient exchange of diagnostic information across clinical locations. Digital radiography was considered vital to the successful implementation of this project as image acquisition, processing, transmission, and archiving would have a significant impact on teleconsults. Furthermore, the recent introduction of advanced imaging techniques such as cone beam computed tomography (CBCT) in dentistry has resulted in an exponential increase in the use of this imaging modality nationwide with the majority of these studies being done in dental offices. The nationwide shortage of oral and maxillofacial radiologists in the US has resulted in dependence on teleradiology services for interpretative services. A teledentistry network was expected to facilitate these consults as well as to ensure that standard of care recommendations developed by professional organizations such as the American Academy of Oral and Maxillofacial Radiology are met. This paper will discuss the clinical implementation of digital radiography, our experience with the transition process including planning, selection of vendors, testing with limited implementation, installation, and quality assurance procedures.

Initial Planning

In January 2004, the UFCD contracted with the university's Center for Telehealth to assist with the implementation of the digital radiography rollout. As part of the project management role, the Center for Telehealth met with each of the department chief to review the proposed work plan and estimate hardware, software, and personnel needs. It also allowed the implementation workgroup to better understand any potential bias to introducing new technology. It was understood that the existing information technology (IT) infrastructure would need to be upgraded to meet the demands of image storage and transmission. The IT depart-

ment worked closely with the workgroup to evaluate the existing network and drew up a plan to upgrade and remodel the existing network.

Table 1 lists the facilities and services falling under the purview of the UFCD. It was evident that a PACS would be necessary to ensure the integration of different systems deployed enterprise-wide. Very few dental PACS products exist. Other pieces of image management software supplied with commonly used dental clinic management systems using multiple types of proprietary image formats were available; however, experience with these algorithms was limited and the capability to handle DICOM images did not exist. The advantages of using a PACS and redesigning the workflow had been reported extensively in the medical radiology and informatics literature.^{2,3} It was also considered appropriate to use multiple vendor products for image generation to prevent dependence on a sole vendor, as well as to cross-train users including dental students on different systems, thus enabling objective evaluation of different digital imaging hardware and software in dentistry for use in a large healthcare setting. The project was started with the full knowledge that it would be an ongoing process with periodic upgrades, iterations, and changes.

Different image capture modalities were included in the plan. These included charge-coupled device (CCD)-based sensors, complementary metal-oxide-semiconductor (CMOS)-based sensors, and photostimulable phosphor (PSP)-based sensors.⁴⁻⁹ The advantages and disadvantages of each were considered. Due to higher patient volumes, the need for students to use these sensors routinely on all patients, comparable image quality, relatively lower cost of PSP sensors, and the resemblance and similar handling features as intraoral films in many ways, it was decided that PSP-based systems would be used for large-scale image capture in most clinical areas. A full mouth series of radiographs comprises of 18–21 individual images captured of selected areas of the oral cavity and is quite unlike a conventional single imaging study. Within the UFCD at the Health Sciences Center (HSC) at Gainesville, Florida, Oral and Maxillofacial Radiology (OMR) does the bulk of imaging, while other departments acquire no more than four or five intraoral radiographs for spot imaging for follow-up. It was, therefore, decided that one PSP reader unit will be installed in each area to enable selected image generation for specific diagnostic tasks. To facilitate training and

exposure to alternate technologies and to enable faster image generation during intraoperative procedures, CCD/CMOS-based sensors were also made available in OMR and the Endodontics Clinics.

At the time of planning and testing, limited options existed for the selection of such systems. There was a great deal of uncertainty about technical support as some of the vendors were in the process of undergoing corporate mergers and divestment. The decision to test and implement multiple vendor products was, therefore, considered well made. Requests for proposals were sent to leading PACS/dental imaging vendors. When the bidding deadline had passed, only MiPACS (Medicor Imaging, Charlotte, NC, USA) had submitted a bid. Due to funding time constraints, it was not possible to extend the deadlines for different phases of implementation. Review of the bid and further discussions with the PACS vendor indicated that the vendor was willing to work with us to customize the software for our needs and provide ongoing technical support for enterprise-wide implementation. However, other proprietary image processing software provided by manufacturers of digital radiography (DR) and computed radiography (CR), as well as third party software were evaluated for ease of use and interoperability. DICOM standards for use in dentistry were still being developed and most image processing algorithms at that time could not handle DICOM data.

Evaluation of Systems and Clinical Implementation

Following planning, several test units were installed in OMR initially. Initial evaluation of multiple commercially available systems was based on information present in the literature regarding diagnostic equivalency to intraoral films for a variety of diagnostic tasks⁴⁻⁹ and the availability of such systems with acceptable levels of technical support. Gendex DenOptix (KaVo Dental, Lake Zurich, IL, USA) and ScanX (Air Techniques, Melville, NY, USA) were the two major competing PSP-based (CR) systems in the market during this time. DICOM conformance was essential for entering systems into the evaluation project.¹⁰ Gendex had been implemented at another dental school but not on an enterprise-wide basis, and technical support problems had been reported.

Table 1. Facilities and Clinics Affiliated with the UFCD Healthcare System

Facility	Imaging Suites		Technologists	Connectivity	Radiologists	Advanced Imaging
Health Sciences Center, Gainesville, Florida	Extra-oral	Intra-oral				
Radiology	4	8	4	Ethernet	2	Yes
Endodontics Faculty Practice		3	1			Centralized through Radiology
Endodontics Resident Clinic		9				
Endodontics DMD Clinic		6				
Periodontics (includes Research Center)		2	6			
Prosthodontics		1	3			
Operative		2	3			
Oral Health Maintenance Clinic		1	1			
Pediatric dentistry	1	1	5			
Internationally Trained Dentists Program	1	2	2			
Dental Hygeine Clinic		4	4			
Facial Pain Center		1	1			
Off-site clinics						
Jacksonville	1	14	1	T3		
St. Petersburg	1	17	1	T1		
Hialeah	1	12	1			
East side	1	11	6	Fiber		
Oak Hammock	1	2	1	T1		

ScanX was also in the process of being considered for implementation at one other dental school, and adequate technical support was reported as being available. Hence, it was decided to use ScanX for the initial test phase. Likewise, other systems including a CCD/CMOS-based Schick system (Schick Technologies, Long Island City, NY, USA) and a Kodak Super-CMOS system (Eastman Kodak/Carestream Health, Rochester, NY, USA) were also installed for initial testing. The intent was to test the systems for diagnostic performance for routine diagnostic tasks such as detection of caries and periodontitis, as well as to evaluate the technical support available to integrate it with the dental PACS. Proprietary image viewing software that were supplied with the CR and DR products, as well as the dedicated dental PACS were evaluated objectively at this time by employing detection of clinically proven caries on film-based patient images for comparison purposes, using a consensus approach. Two boarded oral and maxillofacial radiologists participated in the consensus process. Radiographs were evaluated for delineation of anatomic landmarks on intraoral images when viewed on 17-in. flat panel color monitors (Dell, Round Rock, TX, USA) in Radiology. Systems evaluated include MiPACS (Medicor Imaging, Charlotte, NC, USA), ScanX image processing software, Schick software, and Emago (Oral Diag-

nostic Systems, Amsterdam, The Netherlands). Based on the need to use multiple vendor products and the reported advantages of PACS, it was decided that a PACS would be the most optimal choice for image distribution enterprise-wide with image capture in different vendor products facilitated via proprietary drivers installed within the PACS. Thus, MiPACS was installed in Radiology to determine interoperability of the various test units, as well as for transmission of photographs for the teledentistry project between different offsite clinics and the Gainesville HSC. A ScanX dental system, as well as a medical grade ScanX unit (capable of accepting large sensor sizes), was installed in Radiology for initial testing. Radiology served to provide a self-contained clinical environment for testing purposes. Image capture was facilitated through MiPACS. All CR and DR vendors worked with MiPACS to generate and install appropriate drivers to enable image capture through a common interface within the PACS. Images acquired with the systems were evaluated by two boarded oral and maxillofacial radiologists as well as other members of the faculty for diagnostic quality based on the identification of anatomic landmarks on radiographs generated on DXTRR phantoms. During the course of the initial testing process, image processing parameters in the PACS were altered to enable optimal capture. Compared to medical radiographs, dental images

are very high-resolution images with pixel sizes ranging from 18 μ in CCD/CMOS-based systems to about 60 μ in PSP-based systems. Evaluation of spatial and contrast resolution using anatomic landmark delineation such as the tracing of the dentino-enamel junction, periodontal ligament space, lamina dura, incipient caries localized to the outer half of enamel, etc. served as objectivity measures for acceptability of image quality. Preprocessing filters were altered to suit the tasks at hand. Several visits by the software vendors and close collaboration with the PACS technical support team were essential to implement these changes. These settings, manually determined using objective criteria, were saved for enterprise-wide implementation. A research facility was also in the process of being set up. Several imaging units that were being simultaneously installed for imaging research were also tested for clinical use in this integrated environment. These included: (1) OC100D—direct digital CCD-based panoramic and cephalometric imaging system with dedicated sensors (Instrumentarium Dental, Milwaukee, WI, USA), (2) Kodak 6000 intraoral Super-CMOS-based system (Eastman Kodak/Carestream Health, Rochester, NY, USA), (3) Kodak 8000—Super-CMOS-based direct digital panoramic unit (Eastman Kodak/Carestream Health, Rochester, NY, USA), and (4) Soredex Digora Optime PSP-based system (PaloDEX Group Oy, Tuusula, Finland). Table 2 shows all the systems tested and used in Radiology for enterprise-wide implementation. Simultaneous installation of these units for the research laboratory facilitated comparison of images with those acquired using PSP-based sensors for existing analog panoramic and cephalometric units that were being upgraded. Phantom heads containing human skulls with overlying tissue-equivalent material to simulate attenuation in the clinical setting were used for this purpose. The direct digital extraoral units that facilitated almost instantaneous image generation performed comparably with PSP-generated images from conventional panoramic and cephalometric units, based on visibility of anatomic landmarks as evaluated by boarded radiologists on standardized displays (17-in. flat panel color monitors; Dell, Round Rock, TX, USA). All units were, therefore, entered into clinical service as well with the conventional units serving as backup. Images were captured directly within MiPACS and distributed UFCD-wide using more than 300 workstations using identical display monitors. ScanX intraoral

(dental) PSP reader performed comparably to the medical grade reader for intraoral examinations during the test phase. The ScanX unit, however, required the sensors to be exposed to white light in a separate flood light box provided by the vendor before they could be reused. Soredex Digora Optime reader already had this feature built-in, as the product had been in use in Europe for several years. Turnaround times were much shorter with the built-in floodlight feature. It was also noted that the Optime sensors were slightly more rigid than the ScanX sensors which behaved like films. However, the advantages included minimal physical distortion of the Optime sensors during placement in the oral cavity (with the patient biting down). Neither ScanX nor Optime sensors sustained excessive scratching of the surface during the test phase. However, the sensors required careful handling as the surface is exposed even though a thin plastic layer protects it. When students were allowed to use it, sensor damage was extensive, requiring training and close monitoring. During image capture, ScanX sensors were protected by only a plastic sealable sleeve, while the Optime sensors lay within cardboard wrapping placed inside a waterproof plastic envelope that could be sealed shut. No major differences were noted in sensor packaging or removal times between the systems once the operator became used to handling them. UFCD decided to retain both CR solutions as neither had any significant disadvantage. ScanX was deployed in most clinics enterprise-wide as Soredex at the time was in the process of restructuring at the corporate level. Both Soredex Optime and ScanX units were installed in Radiology at UFCD's Gainesville HSC location. A dental clinic management system, Quick Recovery (QR; Software of Excellence, Cedar Rapids, IA, USA), which had been in use enterprise-wide, was used as a gateway to MiPACS to facilitate capture of patient demographics at the time of image acquisition, as a radiology information system (RIS) for dentistry did not exist. QR was used to maintain a log of user access to comply with security regulations. Integration of MiPACS with QR was of importance. It was also decided that no CR studies would be printed. All CR installations would be implemented in a soft copy reading environment only.

MiPACS continues to implement iterative upgrades but the version installed at UFCD did not have the capability to handle DICOM multifile or

Table 2. Image Capture Devices Evaluated and Installed in Radiology at the UFCD

	Source	Type of support
Extraoral imaging units		
OC100D CCD-based panoramic and cephalometric unit with dedicated sensors ^a	Instrumentarium Imaging, Milwaukee, WI, USA	Research grant
Digora Soredex Optime CR system ^a	Instrumentarium Imaging, Milwaukee, WI, USA	Research grant
Kodak 8000 Super-CMOS direct digital panoramic unit ^a	Kodak	Research grant
Upgrading of existing OP100 analog unit to CR ^b		Federal Teledentistry Grant
Upgrading of existing OC100 analog unit to CR ^b		Federal Teledentistry Grant
Scan X medical grade CR system ^b	Air Techniques, Melville, NY, USA	Federal Teledentistry Grant
Scan X dental grade CR system ^b	Air Techniques, Melville, NY, USA	Federal Teledentistry Grant
Intraoral units		
Kodak 6000 Super-CMOS-based DR ^a	Kodak	Research grant
Kodak 2100 digital x-ray sources (8)	Kodak	Research grant
Schick DR system	Schick Technologies, NY, USA	Existing unit
Advanced imaging		
iCAT cone beam CT unit ^a	Imaging Sciences International	Partly supported by grants from corporate sector, Shands Endowment Fund, and UFCD funds
PACS/image viewing, processing software		
MIPACS ^b	Medicor Imaging, Charlotte, NC, USA	Federal Teledentistry Grant
ScanX software	Air Techniques, Melville, NY, USA	Federal Teledentistry Grant
Soredex Digora ^a	Instrumentarium Imaging, Milwaukee, WI, USA	Research grant
Kodak Imaging Software ^a	Kodak	Research grant
iCAT Vision (client viewer)	Imaging Sciences International	Partly supported by grants from corporate sector, Shands Endowment Fund, and UFCD funds
iCAT Master Acquisition Software with 3DVR ^a		Research grant

^aAdditional site licenses for the iCAT, OC100D, Kodak 6000, Kodak 8000, Soredex software, etc. were provided through research grants

^bScanX and MiPACS were deployed enterprise-wide through the Federal Teledentistry Grant

single-file multiimage formats such as those used with computed tomography (CT) or magnetic resonance imaging (MRI). With the recent introduction of CBCT, this has become a pressing issue. UFCD has also recently installed a dedicated maxillofacial CBCT unit, the iCAT (Imaging Sciences, Hatfield, PA, USA) with high-resolution, large area flat panel amorphous silicon sensor (isometric voxel dimension of up to 120 μ) for maxillofacial applications. The ability to view, manipulate, retrieve, archive images, and ensure communication with the hospital PACS (developed in-house) assumes significance therefore. Work continues to progress to achieve this objective in an effort to coordinate patient care within the University of Florida's Shands Healthcare System. Proprietary DICOM software provided by the CBCT vendor (iCATVision, Imaging Sciences International, Hatfield, PA, USA) to view multiframe images is currently being used to transmit CT data from UFCD's Radiology Department to other clinics, pending release of the next version of MiPACS that is reported as being capable of handling multiframe data. We expect a seamless integration of MiPACS with the hospital PACS once the new version is released and the necessary hardware is in place.

RESULTS AND DISCUSSION

Impediments to the Implementation of Digital Radiography at UFCD on an Enterprise-wide Level

Acceptance issues were observed at all levels (faculty, staff, and students) during the phased implementation of digital radiography on an enterprise-wide level. Limitations in earlier versions of proprietary image acquisition and processing software, coupled with known drawbacks in sensor design and technology of earlier generation systems, generated significant reluctance to adopt new technology. Lack of DICOM conformance of software in dentistry and demonstrable interoperability were major impediments to the acceptance of digital radiographic technology in the United States at that time. Additionally, several clinics were using different x-ray sources for image capture using F-speed film (Eastman Kodak, Rochester, NY, USA), some of which did not

have microprocessors to enable the reduction of exposure times. Several of these units were replaced as well and all new and old units were calibrated for use of CR or DR technology. CR required the same exposure times as F-speed film for acceptable diagnostic quality image generation. Dental DR system software has built-in preprocessing filters that effectively suppress image displays resulting from underexposure. Hence, each x-ray unit had to be worked with individually, using a tissue-equivalent phantom, to generate unit-specific technique charts. Education of users and a phased rollout with availability of extensive training including one-on-one hands-on sessions for staff in different clinics were helpful in promoting adoption of new technology across the dental enterprise. However, the inability of current dedicated dental PAC systems to offer similar features as their medical counterparts continue to limit availability of functionality for a variety of tasks in the Radiology Department, including viewing of multiframe images from advanced imaging modalities such as CT.

Unique Needs of Dental Imaging

Image ordering and acquisition entail a certain sequence of events in medicine that includes ordering, scheduling, acquisition, reading of studies, and reporting. Dedicated hospital information system (HIS) and radiology information system (RIS) equivalents for dentistry do not exist and very few dental clinics use an electronic patient record system. Most ordering and scheduling are done on paper. Manual entries are made into the electronic patient record systems as well as the acquisition modalities at the time of image generation. As the workflow is essentially paper-driven at this point, the radiology staff has to manually locate and reconcile patient data and study of interest. Use of accession numbers in medical radiology has not been adopted in dentistry yet. Potential for erroneous entries and lost data is, therefore, high. Integration protocols have to be developed to streamline the workflow and efficiency. Currently, reports are generated either from within the electronic patient record manually or via nonintegrated dictation systems. Electronic copies of the reports are then posted online within the electronic patient record or sent manually to the referring user in hard copy or soft copy format. Significant interruptions in workflow thus exist.

Currently available medical PACS have major limitations for applications in dentistry. These include, but are not limited to, the lack of availability of hanging protocols for dentistry in most systems, inability to communicate with dental DR and CR systems for integrated image capture, lack of post processing filters for use in dentistry, inability to bridge to specialty-specific software such as Dolphin treatment planning software in orthodontics, implant treatment planning and simulation software such as Simplant, and lack of reconstruction schemes specific to dentistry. Efficient chair-side image capture and processing during dental procedures using PACS appears to be central to promoting its adoption in dentistry, primarily at an enterprise-wide level. Centralized imaging is implemented to a large extent at major dental hospitals in the US; however, the need for intraoperative imaging is high under these settings as well. There was a significant learning curve noted with the phased rollout of digital radiography. Digitization of previous imaging studies that were essential to continue treatment was done on an as-needed basis to effect a smooth transition. The IT help desk at UFCD was instrumental in working out numerous issues related to the use of imaging hardware and software with help from the radiologists. Testing and fine tuning of imaging parameters for different diagnostic tasks continued for over a year post implementation using tissue-equivalent phantoms. Unlike medical radiology, hundreds of images captured by students at each work station school-wide needed to be evaluated by the attending faculty before they could be approved and pushed to the DICOM server. Access to PACS was restricted through the clinic management system as the equivalent of a HIS or RIS in dentistry did not exist. An overread/approval process had to be built in to the PACS for real-time archiving of the studies. Any retakes were done before the studies were finalized. In dentistry, laterality and location of individual frames within a set hanging protocol needs to be confirmed by each attending before the studies could be archived. To support our offsite clinics, images were captured locally at the offsite clinics and transferred to the PACS at the UFCD main campus after normal working hours, reducing network load. The studies were read by attendings at these sites, and requests were sent for overreads

in doubtful cases. The local institutions control the network at two of our four offsite clinics, making it difficult to find and eliminate problems because of firewall and virtual private network settings that were in place. It was evident that greater control of network traffic from the offsite clinic was essential in order to resolve problems in a timely manner. However, dental clinics or departments are usually located within major hospitals with their own network communications security protocols. It was necessary to work individually with each of these sites to ensure seamless integration of data flow. UFCD IT personnel frequently travel to these offsites to help troubleshoot network- and storage-related issues.

Training and Calibration of Users

Phased implementation of digital radiography was implemented to encourage acceptance and enable the IT help desk personnel to troubleshoot problems associated with imaging hardware and software before rolling out the technology enterprise-wide. The rollout started with the Department of Endodontics where intraoperative imaging was already being done on a routine basis using DR. These patients require numerous spot studies during the course of the endodontic procedure. Most patients would have an isolation rubber dam in the oral cavity, and endodontic instruments within the teeth as images are captured for making measurements prior to the completion of the surgical procedure and for verification of adequacy of obturation to prevent failures leading to rarefying osteitis. The Endodontics personnel including residents and attending faculty were already working with digital radiography using encrypted notebooks. When PACS was installed, necessary changes were made to the existing clinic management system (QR) to authenticate users. A custom feature that removed the ability of students to delete and/or approve radiographs was added to the PACS. This added an extra layer of complexity that could only be tested in a live environment. Rolling digital radiography out in a limited patient environment also allowed the implementation team to observe any workflow change. As each department was phased in, Radiology simultaneously offered filmless image capture as well for patients from these specific clinics. We also encouraged

faculty, residents, and staff in clinics that had already made the transition to promote digital radiography through peer-to-peer interaction.

Training and calibration of the users was an ongoing process for several months before, during, and after the implementation of digital radiography at the main HSC location, as well as the offsites. Several visits to offsites were required and the workgroup as well as the IT support team provided this service diligently. In addition, all users were asked to contact Radiology for image acquisition- or processing-related questions. A simulation laboratory with numerous workstations running QR and MiPACS with all vendor-specific drivers for image capture was provided for training and calibration purposes. Users could sign up for training sessions held in this space. Additionally, the training session was captured on video and posted on the teledentistry website for viewing by users. It was evident that one-on-one assistance was essential for ensuring a smooth transition to digital radiography and also to minimize calls to the help desk when image transmission, storage, and processing errors occurred. The implementation team was available onsite in full force when each clinic went live. Technique charts had to be revised and posted as each area was using different x-ray sources. Transition from film to digital radiography in dentistry involves a significant change depending on the generation of intraoral film in use.

Dose Considerations

According to the last NEXT survey, more than 80% of dental clinics use D-speed film with round collimation.³ Most dental clinics affiliated with dental schools and hospitals in the United States used dental films which are three generations newer (F-speed) with rectangular collimation that conforms to the size and shape of these films, thus significantly lowering radiation doses. Transition to CR will, therefore, not see a significant reduction in doses compared to F-speed film with rectangular collimation; however, DR will only require a fraction of this dose as the quantum efficiency of these sensors is higher.

CONCLUSIONS

Dentistry offers many unique challenges to the implementation of digital radiography. Use of extremely high-resolution small area sensors, unique hanging protocols currently not supported by various off-the-shelf medical PACS products, need to integrate with several oral and maxillofacial treatment planning and simulation pieces of software, use of CBCT in dentistry, task-specific post processing of images, and the need to integrate seamlessly with medical systems are some of the challenges faced in this area. With the development of a DICOM standard for dentistry, significant strides have been made to address the more critical issues that would dictate its daily use and adoption by specialties within dentistry.

ACKNOWLEDGEMENT

This project was supported by HRSA grant no. D1BTH03696, U.S. Department of Health and Human Services. PI: Teresa A. Dolan, and in part from industry grants from Instrumentarium Dental (Milwaukee, WI, USA), Kodak (Carestream Health, Rochester, NY, USA), Imaging Sciences (Hatfield, PA, USA), Soredex (Milwaukee, WI, USA), and the Shands Endowment Funds. We also wish to acknowledge the technical support provided by Mr. Andrew Everett of the Department of IT, at the UFCD.

REFERENCES

1. Siegel EL, Diaconis JN, Pomerantz S, Allman RM, Briscoe B: Making filmless radiology work. *J Digit Imaging* 8:151–155, 1995
2. Siegel EL, Reiner B, Work Flow Redesign: The key to success when using PACS. *J Digit Imaging* 16:164–168, 2003
3. Nationwide Evaluation of X-Ray Trends (NEXT). Conference of Radiation Control Program Directors. Publication E-03-6-a-1999. 2007
4. Ramamurthy R, Canning CF, Scheetz JP, Farman AG: Impact of ambient lighting intensity and duration on the signal-to-noise ratio of images from photostimulable phosphor plates processed using DenOptix and ScanX systems. *Dentomaxillofac Radiol* 33:307–11, 2004
5. Ramamurthy R, Canning CF, Scheetz JP, Farman AG: Time and motion study: a comparison of two photostimulable phosphor imaging systems used in dentistry. *Dentomaxillofac Radiol* 35:315–318, 2006
6. Wenzel A, Haiter-Neto F, Gotfredsen E: Influence of spatial resolution and bit depth on detection of small caries lesions with digital receptors. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 103:418–22, 2007

7. Hintze H, Wenzel A, Frydenberg M: Accuracy of caries detection with four storage phosphor systems and E-speed radiographs. *Dentomaxillofac Radiol*. 31:170–175, 2002
8. Farman AG, Farman TT: A comparison of 18 different x-ray detectors currently used in dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 99:485–489, 2005
9. Araki K, Endo A, Okano T: An objective comparison of four digital intra-oral radiographic systems: sensitometric properties and resolution. *Dentomaxillofac Radiol* 29:76–80, 2000
10. Farman AG: Applying DICOM to dentistry. *J Digit Imaging* 18:23–27, 2005