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Review Article

# Challenges Associated with Digital Radiology in Dentistry

**Mouayed Karem Hamid[1]* and Steven R Singer[2]**

*[1]Postgraduate Student, Department of Biomedical Informatics, School of Health Profession, Department of Diagnostic Sciences, School of Dental Medicine, Rutgers University, Newark, New Jersey, USA*

*[2]Professor and Chair, Department of Diagnostic Sciences, Division of Oral and Maxillofacial Radiology, Rutgers School of Dental Medicine, Newark, New Jersey, USA*

***Corresponding Author:** Mouayed Karem Hamid, Postgraduate Student, School of Health Professions, School of Dental Medicine, Rutgers University, Newark, New Jersey, USA.

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## Abstract

In recent years, due to advancement in technology, traditional film-based radiology is being replaced with digital imaging technology. The goals of conversion should be determined and dentists should be aware of the challenges which may exist during the transition phase. Today, many dental schools worldwide have shifted to computed radiology. This conversion introduces new technologies which are often required to be compatible with existing old and new technology. Techniques for proper integration and optimal interoperability must also be considered. However, these advances are associated with a group of challenges. These challenges may be associated with the decision to proceed with the conversion, phases of introduction of digital radiology into the oral radiology clinic, technique disadvantages, selection of the equipment digital receptors for the acquisition, selection of hard and software vendors, and issues related to integration with the Electronic Health Record (EHR). Workflow issues may conflict with other clinical and administrative functions. This article provides an overview of challenges associated with conversion to digital radiology, digital image receptors, and techniques and highlights encounters associated with decision to switch to digital radiology, as well as integration and interoperability issues.

***Keywords:*** *Digital Radiology(DR); Challenges; Imaging Technology; Conversion; Image Receptors; Acquisition*

## Introduction

Dental radiology is one of fundamental tools used for assessment of the hard tissues of the oral cavity, as well as obtaining appropriate differential diagnoses in dental practice. For more than 100 years, dental x-ray film, a variation of photographic film, has been used as the medium for acquisition, viewing, and storage of radiographic images. In recent years, due to advancement in technology, traditional film-based radiology is being replaced with digital radiology (DR).

In late 1980s, the first intra-oral digital sensors were developed for use in dentistry. Unfortunately, the early systems could not capture panoramic and cephalometric images, which made it impossible for private dental offices and clinics to entirely abandon film processing and fully adopt digital technology [1]. Over the ensuing years, the technology and scope of digital imaging expanded to encompass both intraoral, cephalometric, and panoramic imaging. At the same time, digital dental office management systems were developed. These systems integrated with newly developed imaging software and hardware to optimize utilization of the technologies.

Digital radiology plays a significant role in disease diagnosis in dental practice. This is mainly due to the ability of the medium to display both normal and diseased tissue with a relatively high rate of sensitivity and specificity. When combined with clinical data, the

diagnostic efficacy improves. To derive the optimal benefit of DR in clinical sitting, it is important to provide widespread intraoffice access to images and other data through a network office system that integrates all aspects of the electronic patient records. Additionally, when new technology such as digital radiology is implemented in the dental clinic, it is essential that all members of the department and office staff are committed to the change, receive training, and have an opportunity to prepare before introducing the new modality to patients. These precautions will allow the clinician and staff gain confidence using new technology and be able to present it in positive manner to the patient for a transition smoother [2]. Furthermore, preparation will minimize or avoid challenges associated with the transition.

With the decision to proceed with the conversion, other issues related to phases of introduction of digital radiology into the oral radiology clinic or office, as well as technique disadvantages, selection of the equipment digital receptors for the acquisition, selection of hardware and software vendors, and integration with EHR must be considered.

## Digital Imaging

Digital dental imaging originated in France in1984. Trophy Radiologie, (Marne La Vallee, France), was the first company in Europe to introduce dental digital radiography. The first system was named Radio Visio Graphy in 1987 by Dr. Francis Mouyen [3]. Advancement in technology led to support in the U.S dental literature and the first article about digital imaging technology was published in 1989 [4]. Since that time, the field of digital radiology continued to flourish and has been constantly enhanced by development and improvement in image receptors, computer soft and hardware, as well as technical support.

*Figure 1*

*Figure 2*

***Figure 1 and 2:*** *Digital Imaging, Adopted from http://www.dentistryiq.com/articles/2013*

## Image Acquisition

Image acquisition is dependent on the digital image receptors, which work in different ways in creating the digital image. However, there are two advanced technologies in acquiring digital images without an analog precursor;

A- Direct technique, two systems are available: {i} direct imaging {ii} Semi-direct imaging.

B- Indirect technique, by scanning conventional radiographic film using a flatbed scanner as described in figure 3.

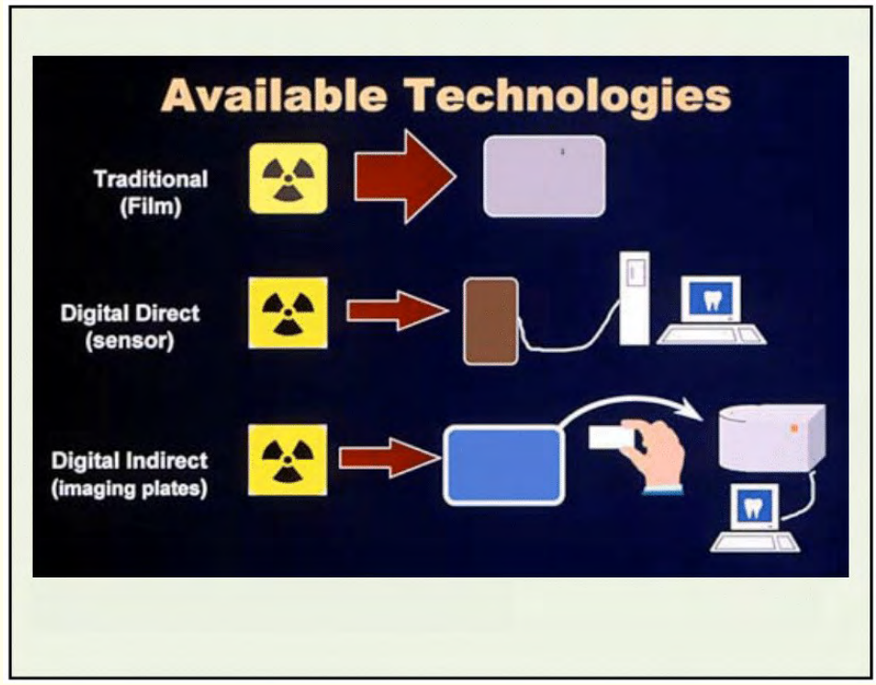


***Figure 3:*** *Techniques of image Acquisition.*

*Image curtesy of The Journal of Contemporary Dental Practice*

The direct technique images, acquired by direct imaging, are based on use of solid-state sensors, which are charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) based chips, while in semi-direct technology, images are acquired using a phosphor plate (PSP) [5]. Sensors are available in various sizes: 0, 1 and 2 for different patients, usage and selection are depending on the purpose, patient age (Figure 4).


***Figure 4:*** *Adopted from: www.dentalcare.com/en-US/dental-education/continuing-education/ce350/ce350.aspx*

## Types of Digital receptors (Sensors)

**Charged Coupled Device (CCD):** CCD was the first type of image receptors used for intra oral digital imaging and was invented in 1987. Wired CCD sensors have cable leading from the sensor to an interface, which is connected to a computer in the operatory (Figure 5).


***Figure 5:*** *CCD.*

### Challenges related to CCD:

- One of the major challenges with CCD sensor is the thickness, as the sensors are much thicker and more rigid than conventional film. This might be not well-tolerated by some patients, and in some cases, it is difficult to position the sensor in the patient's mouth with a minimum of discomfort. As a result, it may be more time-consuming to capture an image, when compared to film.
- The size of the actual CCD surface is significantly small than that of film (31 mm x 41 mm versus 36 mm x 27 mm). This may lead to missed anatomy. In typical use, radiographic technique must be modified to accommodate the small image receptor.
- Interference of the cable attached to the image receptor during its placement and this may eventually lead to cable damage. This issue may be solved by the invention of wireless sensors (Figure 6).


***Figure 6:*** *Direct digital receptors are of rigid construction with an attached electrical cable.*

*Source: Schick Technologies, Inc., Long Island City, New York*

- This system is relatively expensive due to specialized hardware and software. CCD requires special hardware digital converter, analog-to-digital converter (ADT) for taking the voltages generated within CCD and convert them into numbers which used to represent the image digitally [6]. This increases the cost of the system.

- Increased number of retakes of radiographs, due to deceased actual active surface of the receptor for image capturing. Estimated as 60% of the surface area of the size of x-ray film it replaces [7].

### Complementary metal oxide semiconductor/active pixel sensor (CMOS/APS)

Less expensive and durable with similar resolution to the CCD sensor, this system works by direct technique for image acquisition and does not require charge transfer. It requires less system power to operate than CCD [8].

**Photostimulable phosphor plates (PSP):** PSP, also known as storage phosphor plates (SPP), are considered to be a semi-direct technique. SPP system uses plates, similar in appearance and feel to film, comprised of a flexible polyester base coated with crystalline emulsion of europium-activated barium fluorohalide compound. After SPP plates are exposed to x-radiation, they are placed into a laser scanner (Figure 7) to convert energy from the "stored" electrons into visible light. Then, this analog signal is converted into a digital image which viewed on computer monitor [7].

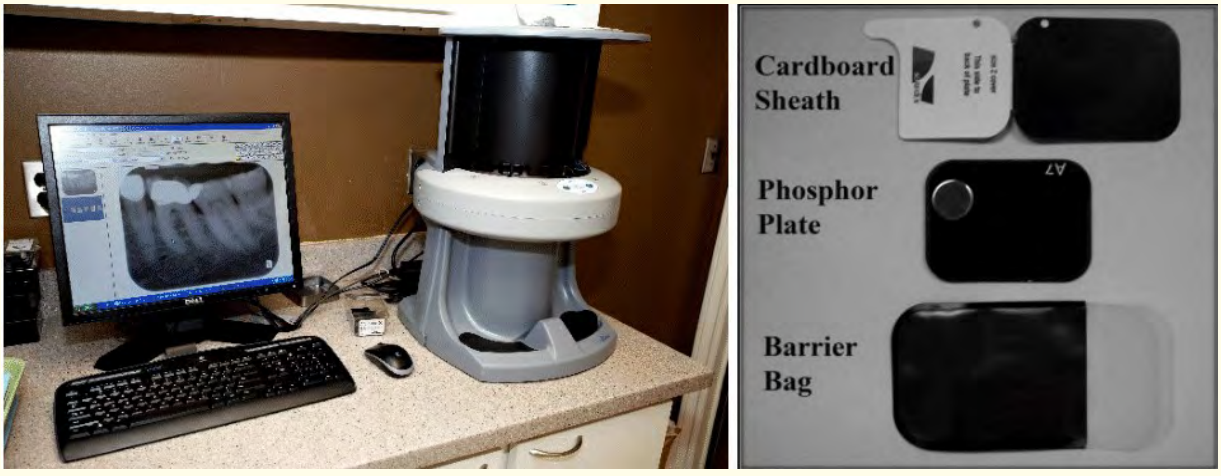


***Figure 7:*** *Direct digital receptors are of rigid construction with an attached electrical cable.*

*Image adopted from: http://www.oooojournal.net/cms/attachment/2004371775/2018388952/gr1.jpg*

### Challenges with using PSP

This technique is slightly more time consuming than CCD or CMOS sensors, due to the additional scanning time and time required to erasing the plate. Following exposure, plates must be removed from their contaminated barrier pouches, run through the scanner, "erased" with bright light, and repackaged in clean barrier pouches prior to using again. For plate erasure, some scanners incorporate an "erase" cycle within the scanner itself. With other units, the plates are moved to a separate plate eraser following the scanning process.

### Digital image formation

A digital image is formed by a collection of a group of cells (pixels) arranged in a matrix of rows and columns, these cells described as three numbers which are organized in X and Y axes and gray value. The gray value of each cell is a number that correspond to the intensity of the radiation at that point during receptor exposure (Figure 8).

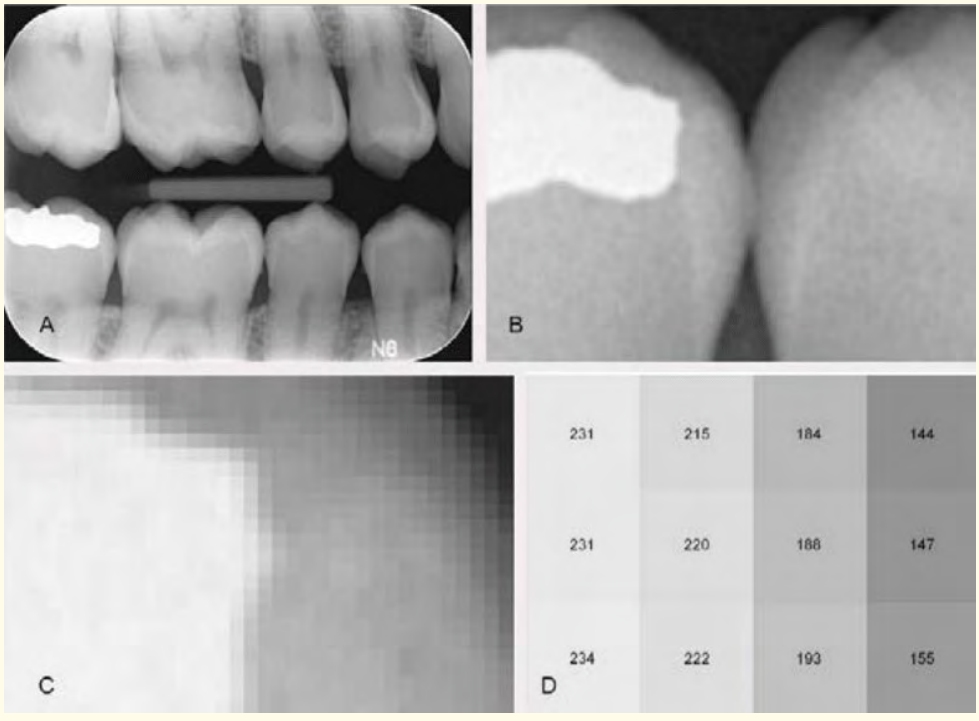


***Figure 8:*** *An example of digital image data (bitewing), the image contains rows and columns of individual pixels, each having their own gray scale pixel value. The original image (A), zoomed portions of the image (B-D) where pixel values corresponding to gray scale values have been marked (D). In x-ray images, the gray scale value of the pixel depends on the amount of radiation incident to the detector at the pixel location*

*Adapted from: NORD I S K T E M A: DI G I T A L E T E K N I K K E R, Mika Kortesniemi, Marja Ekholm and Tomi Kauppinen, The handling of digital images. 2014*

The solid-state image receptors are made of silicon and are arranged in an array of light sensitive pixels. After the exposure of the sensor, x-ray energy is converted to proportional number of electrons, and then this electron transferred in a sequential manner to a read–out amplifier (Charge Coupling). This analog signal is converted to a digital signal and the radiographic image will be visible immediately on the computer monitor [9].

## Challenges with intraoral digital radiology

Despite all of the advances in digital radiology technology, some of limitation and challenges continue to exist.

## Sensor placement

Placement of rigid bulky sensor can be challenging, especially in patients with an exaggerated gag reflex, shallow palate, or narrow palate. Manufacturing sensors with smaller design, rounded corners, and different materials to cover the sensor have been employed to address these challenges [10].

## Cost

Some of intra oral sensors (CCD) require a digital converter (ADT). As a result, each intraoral sensor can cost as much as $10,000 in addition to the cost of computers, software and additional sensors.

### Learning Curve

Dentist and staff skills plays a significant role in mastering and adaption of new techniques and technology. Although the change in technique from film to digital sensors is relatively minimal, some assistants and dentists have difficulty and struggle with basic computer features and image enhancement for better diagnosis. PSP sensors may have a shorter learning curve than CCD and CMOS sensors, probably due to the similarity in handling characteristics of film and the PSP plates. Over time, learning and continued practice, as well as improvement in sensor design will overcome these challenges [10].

### Infection Control

Considering that digital image receptors are not disposable, it is essential to follow the manufacturer's instructions in handling, cleaning and disinfection procedures as using them for multiple patients. No digital sensor presently available can be steam autoclaved, which is the standard for sterilization. All sensors must be covered by fresh protective barrier before each use [11]. Additionally, the integrity of the barrier must be maintained throughout the process of exposing the images.

### Loss or breakage of sensors

Wired sensors are vulnerable damage to, as patients may bite on the wire, affecting the efficiency of the receptor. Wireless image receptors are susceptible to breakage from dropping, so dental professions should handle them carefully [12]. PSP plates are susceptible to scratching during scanning and re-bagging procedures. Further, severe bending or folding can damage the plate. Damaged PSP plates must be replaced.

### Lack of universal use of digital radiography

Not all dental offices are equipped with digital radiology. However, continuing dental education courses are important for dental professions to be up-to-date. As "some practitioners are accustomed to reading digital images, almost all practitioners are accustomed to reading conventional radiographs" [12]. As more dental school convert to digital imaging, more dentists will be trained in digital radiographic techniques.

### Digital Image manipulation

Digital image storage, back up and exchange should be managed with maintaining patient privacy and confidentiality. Management protected healthcare information (PHI) is governed by Health Insurance Portability and Accountability Act (HIPAA). Nonetheless, it is essential to ensure secure implementation of the process of digital imaging to protect against unauthorized users as well as against loss [11].

### Challenges associated with conversion

Conversion to Digital radiology (DR) in dentistry is associated with some obstacles starting with making a decision to go with adoption of this technology. For an educational institution to make a transition to DR, research, planning, and consensus should be achieved before selection of the vendor.

For the program director or person leading the transition phase, certain steps need to be considered to avoid and/or minimize the challenges associated with the process of transformation and implementation:

- Consider inviting vendors to present their products at different sessions. Comparison and discussion sessions should be held soon afterward to consider the attributes of each system under consideration.
- Consultation with colleagues at other schools that use digital technology, in addition to visiting schools that have adopted DR can be helpful in decision as well.

- Discussing and setting goals for technology implementation with associates and/or speaking with manufacturers and their local representatives.
- Challenges can be overcome by following a well-established plan. A suggested plan can be found in Dr. Joe Gatti's guidelines table [13] for the decision-making process for transition to digital radiology technology;
    - Clarify what benefits can be expected from a change to digital imaging. Additionally, clarify what liabilities may be incurred from the change.
    - Encouraging participation in the decision-making process, and encourage an informed consensus by obtaining feedback from stakeholders. This should include faculty, staff, and students at the institution.
    - Determine the anticipated return on investment, both in monetary costs, as well as educational, service, and research benefits.
    - Develop an implementation plan with a clearly stated rationale and intermediate goals. For example, certain areas of the school may be selected for early conversion to digital imaging due to cost considerations, physical location, patient care issues, administrative benefit or any combination of these factors. This should all be inclusive and transparent. Digital hubs need to be established with practice management and clinical software, to avoid buying any additional bridging software to integrate different software programs that are in use. Interoperability challenges will be discussed later [13].

## Computer and dental radiology

A computer is an integral part of digital radiology process. After the image is captured and the stored information received from the CCD or CMOS sensor, the image will be displayed on the computer monitor. As previously mentioned, this speed is very useful in endodontic and implant surgical procedures. The image may be stored permanently on the computer's hard drive, printed on a hard copy or transmitted electronically to insurance companies or referring dental specialists [14].

***Figure 9:*** *Digital image seen on Computer screen.*

*Image adopted from: http://vrtp.ru/index.php?showtopic=13278*

### Phases of introduction into oral radiology clinic

According to Dr. Joe Gatti guidelines table [13] for decision making process for transition into digital radiology technology (see previous point 5.4).

### Challenges with selection of hard and software vendors

It is important before purchasing a specific system to determine whether the digital radiology software is compatible with practice management and other software used in the clinic. If this is not done, the issue of incompatibility will prevent integration of the radiographic images into patient's her, which may lead to conflicts in work flow [15].

### Challenges related to integration with EHR

"Integration of digital radiology (DR) into the EHR is a complex step and depending on the compatibility of the vendor. Basically a key component for the EHR is to provide simple access to the patient's previous data. For instance, the patient information and scans (CT, MRI) in the radiology department can be accessed quickly and smoothly by faculties and students from other departments. "Currently many practices do not have a patient portal because their EHR or radiology information system (RIS) does not have an integrated package for it. This often happens when the vendor simply does not write code for a new module and expects practices to find another third-party solution to "bolt on" to their system" (Steve Deaton, Viztek, November 2012).

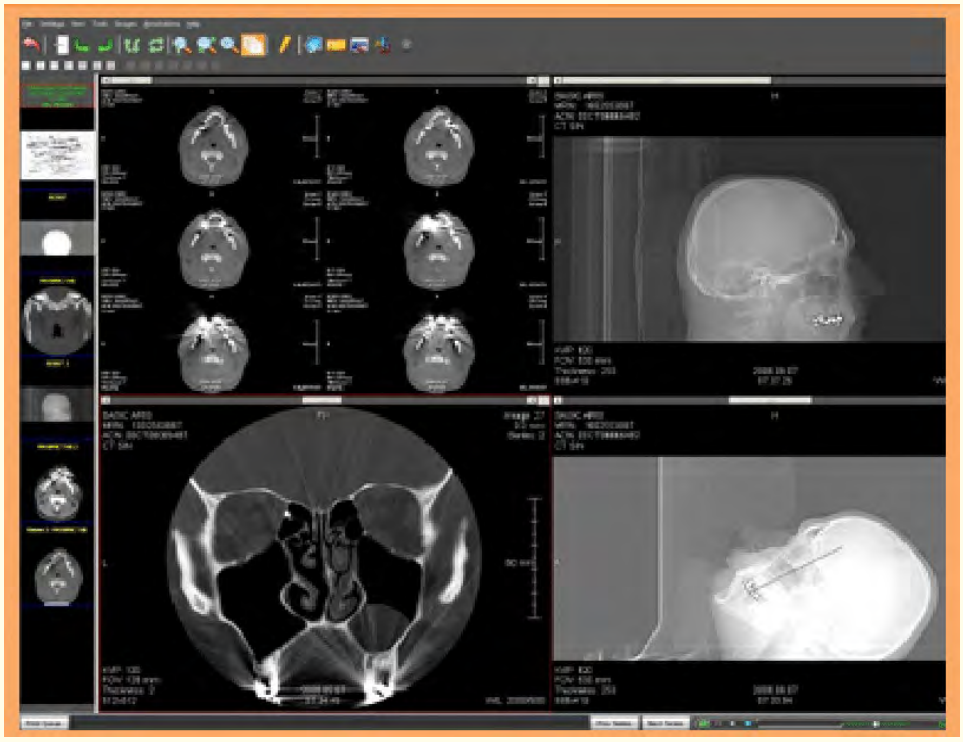

***Figure 10:*** *Viztek's Opal-RAD PACS encompasses a powerful suite of digital radiology tools to achieve a fully integrated patient database, imaging and communications system. IMAGE COURTESY VIZTEK*

### Post installation problems and testing of equipment and software

Digital equipment is calibrated at the manufacturer's site, but conditions change when the equipment is installed on site. Issues and glitches after installation of DR system in dental clinics are expected, however limitations of image generation and transmission may very well have been reasons for the late adoption of digital radiology within the dental community.

***Figure 11:*** *Adopted from: http://www.my-dentist.org/digital-x-rays*

The use of digital radiology in dentistry is growing. It is different from medicine, as the dentist requires that the radiograph be available chairside to interpret the images. Until recently, images acquired using the proprietary software could not be viewed in other programs without some data loss. However, the use of the Digital Imaging and Communications in Medicine (DICOM) standard in dentistry has addressed these issues and integration between applications became more convenient [16].

### Challenges related to training of Faculty, Staff and Students

Vendors and radiology department managers must work together with IST departments to determine training expectations in advance, which includes pre-assessment and post assessment of trainees' skills and time expectations. Once applications trainers arrive on site, managers must support radiographers' attendance at training, and trainees must remain engaged throughout training completion. It also is essential that all members of the digital imaging team, including service engineers, have training and updated competence in addition protection.

## Conclusion

Presently, implementation of dental digital radiology in dentistry is essential for record keeping, reimbursement, and appropriate management of imaging records. Furthermore, it is a helpful and powerful tool in diagnosis of dental diseases and disease of the orofacial region. However, this technology is surrounded by some challenges and dental professionals should expect technical and behavioral challenges as part of the transition. Nonetheless, avoidances of disappointment in system performance can be minimized by careful purchase planning and realistic expectation of hardware, software, and personnel.

## Conflict of Interest

There is no conflict of interest.

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