Applying the New ADA Quality Assurance Standard to Digital Intraoral Radiographic Systems

Authors; Peter Mah[a], DMD, MS, Allison Buchanan[b], DMD, MS and Teresa E. Reeves[c], DDS

a. Dental Imaging Consultants LLC, San Antonio, TX, and Consultant, Air Force Medical Readiness Agency, San Antonio, TX, USA

b. Associate Professor of Radiology Department of Oral Biology &Diagnostic Sciences, The Dental College of Georgia at Augusta University, Augusta, GA, USA.

c. Associate Professor of Oral and Maxillofacial Radiology, United States Air Force Postgraduate Dental School, San Antonio, TX, USA and Air Force Military Consultant for Oral and Maxillofacial Radiology

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Abstract: This article is intended to describe the appropriate quality assurance (QA) methods for digital intraoral radiographic systems in accordance with ADA/ANSI standard 1094. This article goes step by step through the digital imaging chain (intraoral x-ray generator, the image display device, and the image receptor and acquisition software) so that the reader achieves a complete understanding of what is required to successfully implement a comprehensive QA protocol within their own practice.

Introduction/Background

Quality assurance (QA) is defined as the planned and systematic activities necessary to provide adequate confidence that a product or service will meet the given requirements.[(1)]The need for QA with digital intraoral radiography was identified in the National Council on Radiation Protection and Measurements (NCRP) Report 145 (December 31, 2003) which stated, in section 3.4.3.3*Digital-Imaging Systems,* "Procedures for evaluating the performance of digital-imaging systems are quite different from those used with film or screen-film image receptors. By using suitably designed phantoms and software, image quality aspects such as resolution, contrast, signal-to-noise ratio, and contrast-to-noise ratio may be measured directly. However, the required standards, apparatus and software for dental systems do not currently exist. These limitations are important factors when considering the purchase of digital-imaging systems."[(2)]

In February 2020, the American Dental Association (ADA) Standards Council on Dental Informatics (SCDI) updated the ADA Technical Report 1094, Quality Assurance for Digital Intra-oral Radiographic Systems, from a technical report to an ANSI/ADA Standard (ADA Standard 1094 in Process).[(3)]ANSI/ADA Standard 1094 will serve as the national standard for all dental facilities. A simple review of recommendations by the state dental associations as well as

the varied inspection requirements for digital intraoral radiography, illustrate the lack of consensus on effective QA protocols for digital intraoral radiographic systems. Publication of ADA Standard 1094 should assist in consolidating an effective quality assurance program nationwide as the ADA is the sole recognized dental standards group in USA.

The purpose of this article is to define appropriate QA methods for digital intraoral radiographic systems to help clinicians when implementing these systems in their practices.

The imaging chain

It is important to be familiar with the digital imaging chain which includes the intraoral x-ray generator, the image display device, and the image receptor and acquisition software. Alterations to any one of these components could result in reduced image quality. Therefore, it is necessary to implement a QA program that includes evaluation of the entire imaging chain. .

Intraoral X-ray Generator

In accordance with ADA Standard 1094,Quality Assurance for Digital Intra-Oral Radiographic Systems(in process), and the NCRP report 177, all x-ray generators should be evaluated by a qualified expert prior to initial use.[3, 4]Additionally, the ADA Standard 1094 (in process) recommends periodic constancy testing (i.e. measuring x-ray output)annually, unless there is a repair or other requirement to necessitate a shorter interval.[3]

Periodic constancy testing is a simple method to assess x-ray tube output and can be accomplished easily with the purchase of a modern electronic x-ray measuring device(sometimes referred to as a dosimeter) and additional training for the dental staff.[3] With the use of modern electronic x-ray measurement devices, the required QA tests may be completed in 10 to 15

minutes. The detector portion of the electronic x-ray meter is placed at the end of the beam indicating device (BID) and the exposure parameters utilized for the adult molar bitewing radiograph are used. These electronic x-ray meters are more than just dosimeters, since a single radiographic exposure will provide radiation output in mR or mGy, the peak kilovoltage (kVp), the exposure time in seconds, the half value layer (HVL) in terms of thickness of aluminum, and the dose rate and number of pulses. **Figure 1** shows an example of an electronic radiation meter measuring intraoral X-ray generator performance. Alternatively, the dental facility may retain the services of an x-ray vendor, dental x-ray equipment repair service provider, state licensed dental x-ray inspection provider or medical physicist to perform these tests on their behalf.

The periodic constancy testing performed by the dental facility is independent of the state mandated tests that state inspectors may perform on the intra-oral radiographic unit. The state mandated inspections are an outside validation of the performance of the x-ray generating equipment whereas periodic constancy testing of the x-ray output is part of the QA program included in ADA Standard 1094 (in process). The required QA checks of the x-ray unit are specified in their respective state statutes for dental radiography. A quick reference to each of the state's applicable radiation regulations for dental imaging can be found at: https://www.aaomr.org/radiation-regulations. Information for the state of California is also provided in the California Dental Association publication: Radiation Safety in Dental Practice.[5] The state mandated inspections usually consist of evaluating the x-ray generator only and in some states recording the ESE (entrance skin exposure or air kerma value). Most states do not get involved with image quality and checking the viewing monitor which will be discussed next.

The Image Display Device

Most modern commercial off the shelf (COTS) monitors with 1920 x 1080 display format are acceptable for viewing intra-oral radiographs.[6-8] There is no need to purchase expensive medical grade monitors capable of displaying 12 bit gray scale images that meet DICOM Part 14 GSDF (gray scale display function) requirements. Since most dental radiographic systems display their radiographic images in 8 bit, with 256 shades of gray, there is little to no benefit to using medical grade monitors. Further, most publications suggesting that DICOM Part 14 GSDF calibration is required for dental viewing monitors have been from comparisons to the medical radiology viewing rooms where viewing conditions can be rigidly controlled and maintained, but this is not practical nor possible in a dental treatment room (DTR). Dental treatment areas require lighting conditions suitable for other dental tasks such as shade selection of restorations and clinical examination. The clinical viewing display in the DTR is used only for short bursts to visualize radiographs as part of a wider clinical assessment of oral health, therefore it is not practical for a DTR display to match an idealized medical grade radiology monitor, calibration and viewing environment.

Instead, the image display device can be evaluated by displaying a standard digital image test pattern. An example of such pattern is the Society for Motion Picture and Television Engineers (SMPTE) Medical Diagnostic Imaging Test Pattern and is available as freeware (**Figure 2a**). Additionally, a software vendor may provide a similar test pattern within the dental display software(**Figure 2b**).This QA test protocol for the image display device shall be performed monthly and can be made in just a few minutes by the dentist, dental hygienist or dental auxiliary.[3]Proper adjustment of the image display device should be performed under proper viewing conditions (see below). The SMPTE test pattern image should be inspected for

the absence of artifacts such as bleeding of bright display areas into dark areas or blurring of spatial resolution patterns.[9, 10] Additionally, appropriate dynamic range can be confirmed by ensuring that both the 5% and 95% inner squares are distinct from their respective adjacent 0% and 100% outer squares.[3] The contrast and brightness settings of the monitor should be adjusted until all the gray levels are visible as well as delineation between the 5% and 0% and the 95% and 100% squares is achieved.[10]

The viewing environment, i.e. the level of ambient lighting, may affect the perceptibility of contrast differences in the digital radiograph.[7, 11-13] In fact, the brighter the background lighting, the higher the screen luminance necessary for perception of grayscale changes.[14] Thus, the optimal viewing conditions are a quiet and darkened room.[3]

Additionally, the majority of the light from the display device should be from the digital image itself and; therefore, use of a black background when viewing radiographs is appropriate.[3] Dimmed ambient lighting is the optimum environment for image interpretation; however, obscuring or hooding of the image display device can reduce the ambient lighting by an average of 70% and can be used if there is too much ambient lighting in the dental viewing environment.[7, 15]

Most image display devices are very stable over time; however, optimizing the image display for tasks other than radiographic interpretation may affect diagnostic performance.[3] When LCD monitors are optimized for color display, the luminance of the display monitor decreases making it more difficult to discriminate grayscale differences.[16, 17] Grayscale display monitors are operated at a higher luminance than color display monitors and the loss in ability to visualize the grayscale is due to the decreased luminance that occurs.[17, 18] Therefore, the use of personal color photos as screen savers is discouraged since this will cause automatic

optimization of the monitor to display colors and; therefore, reduce the ability of the monitor to properly display grayscale values from dental radiographs.

Intraoral Image Receptor (to include acquisition software)

Intraoral digital image receptors should be evaluated initially (i.e. acceptance testing) and at periodic intervals. Two recent publications identified issues with new, unused intraoral image receptors.[1, 19] These issues included artifacts, delamination (uncoupling of scintillator), non-uniformity (light and dark areas, dark banding), and latent images.[1, 19] **Figures 3a and 3b** provide examples of delamination and non-uniformity.

The first step in the evaluation of a digital image receptor should be a physical examination of the image receptor. Owing to differences in the construction and requirements for the physical inspection of direct capture and indirect capture receptors, these will be divided into two sections.

Direct Capture Intraoral Image Receptor (CCD and CMOS) - Physical Inspection

The direct capture image receptor should be continually checked for integrity to make sure that the product is intact, not split or missing part of the protective plastic casing, the sensor wire is not frayed, broken, kinked or damaged, and the computer attachment is intact. Significant bite marks on the active sensor side of the image receptor may be an indication of internal damage affecting image quality.

Indirect Capture Intraoral Image Receptor (PSP) - Physical Inspection

PSP inspection involves looking for obvious scratches, bitemarks, and physical damage such as bent plates and separation or delamination of the phosphor layers from the base. Examples of damaged PSP plates is shown in **Figure 4**. Additionally, with PSP digital imaging systems, the scanner is another part of the imaging chain which must be inspected. NCRP Report 177 recommends regular cleaning of the PSP plate and scanner transport assembly as well as performing radiographic phantom tests on PSP plates every 40 exposures per plate.[4]

Image Optimization and Radiation Dose Control

The maximum diagnostic yield of the image receptor is defined as the highest spatial and contrast resolutions achieved while maintaining visibility of the full dynamic range (i.e. all aluminum steps visible in stepwedge, including steps of air and lead). The optimal exposure is defined as the exposure parameters that produce the maximum diagnostic yield for the image receptor at the lowest radiation exposure.[1, 20-22] The radiographs produced at the lowest and highest radiation exposures while still maintaining the dynamic range represents the exposure range or latitude of the image receptor. The latitude of the image receptor may vary slightly depending upon the combination of components in the imaging chain such as the intraoral x-ray unit (i.e. generator), the image acquisition software and the image display device. Even with the same brand, model and vintage of digital intraoral image receptor type, there are measurable differences in image quality using the same radiographic exposure parameters with the same x-ray generator.[21, 23]

Quality Assurance Phantoms

The method to determine the optimal exposure with a radiographic phantom designed for digital intraoral radiographic systems is explained in ANSI/ADA TR1094, Mah et al., Udupa et al, Walker et al, Reeves et al and Buchanan et al.[3, 20-22, 24]This method works for all combinations of intraoral x-ray generators, short and long cone round and rectangular collimators (i.e. BIDs), image receptors (direct and indirect capture), viewing monitors, and acquisition software. To determine the optimal exposure, the radiographic phantom should have repeatable projection geometry, and the ability to measure: the dynamic range across the entire range necessary for dental imaging (no attenuation to full attenuation of the x-ray beam), spatial resolution, contrast perceptibility, and latitude.[1, 3, 4, 10]Using a contrast detail phantom alone does not allow one to evaluate the spatial resolution, dynamic range or latitude of the intraoral radiographic system. Likewise the use of a spatial resolution pattern alone does not allow the user to evaluate the contrast perceptibility, the dynamic range or latitude of the intraoral radiographic system. Additionally, use of a typical aluminum stepwedge alone does not allow one to identify the optimal exposure of the image receptor (**Figure 5**). While gross under and overexposure is apparent in **figure 5**, there is no way to identify the optimum exposure due to the lack of measurement of spatial and contrast resolutions, and inability to determine full dynamic range due to lack of air and lead steps. It is critical that the contrast perceptibility, spatial resolution, and dynamic range of the intraoral radiographic system be evaluated simultaneously within the same radiographic image. Additionally, the projection geometry must simulate intraoral projection geometry to prevent erroneous errors owing to properties of the inverse square law.[4] The reader is cautioned to ensure that the QA phantom they acquire for their dental facility meets all the criteria mentioned above as specified in ANSI/ADA Standard 1094.

Uniformity Evaluation

Uniformity tests, sometimes referred to as flat-field tests are implemented for QA in medical radiology and QA in dentistry for CBCT imaging. Uniformity tests/evaluations have been promoted as an additional method to validate the performance or to identify problems with digital intraoral image receptors.[3, 10, 25-27]

Table 1 lists each of the proposed uniformity tests along with any frequency, method and type of uniformity evaluation. The two types of uniformity tests proposed are qualitative evaluation or subjective assessment, and a quantitative assessment with objective image analysis.

In the absence of an appropriate QA phantom for digital intraoral imaging, a uniformity test may be able to identify gross performance issues. However, when considering a uniformity test for digital intraoral image receptors there are a number of factors to take into account. At present, there is inadequate research on this subject and no definition exists of what non-uniformity value constitutes a failure of the intraoral image receptor (5% variance for medical equipment).[25] Additionally, to understand what information is gained through using uniformity tests in intraoral imaging one must consider several factors, including: the geometry of the x-ray beam, the effects of software, the construction of the direct digital sensor itself, the length of the BID, and the ability of the uniformity test to be performed on the digital intraoral system.

From the authors own experience, the same sensor tested over a number of trials will exhibit some differences and may lead one to believe that this is due to inconsistent sensor performance. Is this really inconsistent sensor performance or due to photon flux from the manner in which x-rays are generated? Dental x-ray generators themselves do not emit a uniform radiation field such that the x-ray beam is more intense in the central region where the focal spot is located, and less intense at the periphery. This phenomena is also seen with a flashlight beam

in which a point source of energy with increased intensity is located in the central region and there is a decreased intensity on the periphery. The same problem exists in medical radiology, but in medical QA tests the x-ray source is set at a distance of 180 cm away from the image receptor to minimize the effects of the variations in the x-ray beam intensity.[25] Since the effect of a point source of energy dissipates with distance, the increased source to image receptor distance allows the x-ray beam to be more uniform at the level of the image receptor. At source to image receptor distances less than 180 cm, the x-ray source itself is a source of non-uniformity.

Within the medical radiology community, flat field or uniformity testing is carried out with raw unprocessed radiographic images. In digital dental radiographic systems, we do not have access to raw unprocessed images. Rather, the best radiographic images that we can obtain for uniformity testing in dentistry are minimally processed (see Software, next section).[28] The problem is that the end user has no control over most pre-processing protocols, so when a minor image defect is captured, and certain processing protocols are applied (i.e., histogram stretch-on) the subtle non-uniformities can be exaggerated. On the other hand, if you observe what you perceive to be a uniform field it is also possible that software processing has given rise to the uniform appearance and; therefore, what is perceived as a uniform flat field may represent an artifact caused by image processing software. (**Figure 6a and 6b**)

The uniformity test should take into account the function of the fiber optic plate of the direct capture sensors. The fiberoptic plate directs the visible light released from the scintillation layer produced when it comes into contact with x-ray photons onto the CCD/CMOS detector. The x-ray photons closer to the focal spot strike the scintillator layer in a parallel manner and the light generated from this interaction is better transmitted through the narrow columns of the

fiberoptic plate.[29]Conversely, the x-ray photons at the periphery of the x-ray beam are divergent and are not as easily transmitted through the fiber optic layer.[30] This discrepancy leads to a non-uniform intensity image on the resulting radiograph. To obtain a more uniform dispersion of light through the fiber optic layer, the x-ray source should be placed farther back from the image receptor.[30] This geometric factor could be another source of non-uniformity which is not a problem with the digital image receptor itself.

The problem of geometry and distance between the x-ray source and image receptor is further magnified by users of short cone collimators (i.e. BIDs) at only 20 cm versus long cone collimators (i.e. BIDs) at 30 cm source to detector distance due to the inverse square law. Most manufacturers of wall mount and portable dental x-ray generators supply only short cone (i.e. BID) with an additional cost for the long cone extension. It should be noted that all handheld x-ray generators use a 20 cm or a short source to detector distance.

Unlike CBCT units, there is no requirement for digital sensor manufacturers to provide meaningful methods to evaluate uniformity testing on their intraoral sensors. How do we address the concern of digital intraoral systems not being amenable to uniformity tests such as the Gendex GXS-700 imaging system in the Hellen-Halme et al paper (**Table 1**)?[27]The GXS-700 was also evaluated in the Reeves et al paper, and only two of 25 sensors were identified with uniformity issues.[1] One sensor had a slight delamination in the bottom right corner and another sensor had a vertical striation or banding problem.[1]**(Figures 3a and 3b)**

Additionally, it is possible to identify non-uniformities with a radiographic QA phantom that meets the requirements of ADA/ANSI Standard 1094 (**Figures 3 and 4**) that allows the user to determine the optimal exposure and identify gross non-uniformity of the image with a single

QA test. Flat field uniformity evaluations for dental intraoral sensors are only qualitative visual observations.

Software

It is important that there is minimal image processing from software when determining the optimal exposure for the image receptor.[1, 22, 28, 31] One must turn off the enhancement options within the software to produce a raw image. This creates a minimally processed image, rather than an actual raw image, since some of the software enhancements are programmed by the manufacturer or installed by the digital radiography system installer without the end-user having control over them.[28] Changes in software settings that can be made to produce a minimally processed image include: setting the gamma value to 1 (a gamma value of 1 is equivalent to no gamma correction), turning-off sharpening and smoothening filters, and histogram adjustments.[1]

Once the optimal exposure has been determined, then subsequent images can be acquired for comparison to ensure that any software filter that is applied does not result in loss of data. This allows one to assess the effects of software manipulation on diagnostic quality. Therefore, a comprehensive QA program should include appropriate evaluation of the effects of software on the diagnostic quality of the image. Nevertheless, it should be stressed that software changes, regardless of when in the imaging chain they are applied, should not be used in an attempt to compensate for an incorrectly exposed radiograph. One must start with a properly exposed radiograph in order to benefit from software adjustments.[31]

Discussion

When QA for digital intraoral radiographic systems have been discussed to ensure consistent high quality diagnostic radiographs, it seems that the opinions and thoughts are just as varied. With the introduction of ADA Standard 1094, it is hoped that there will be a migration toward a practical and scientific approach to address this issue. It is clear that there is a need for QA with these digital radiographic systems just as there was with film based imaging where film contrast, time and temperature were checked daily. Even so, some dental providers question why they need to be concerned about QA in dental radiography.

To understand the requirements surrounding QA with regards to digital intraoral radiography one must know the differences between a standard, a guideline, a policy, a position statement, recommendations and a statute. A standard is the legal duty of a professional, in this case the dental health care provider, to exercise the level of care, diligence, and skill prescribed in the standard. This is the case with updating the ADA Technical Report 1094 to ADA/ANSI Standard 1094. "The American Dental Association (ADA) is an ANSI accredited standards developing organization. ADA standards have been approved as American National Standards by ANSI and thus they are designated as ANSI/ADA Standards. Further, ANSI is the U.S. member to ISO. The U.S. TAG for ISO/TC 106 determines the U.S. vote on all dental standards and provides this input to ANSI for ISO/TC 106."[(32)]As such, the ADA is the sole standards group for dentistry in the USA and failure to adhere to an ADA Standard would be deemed as failing to meet the standard of care. The reader should also be cautioned that not all items mentioned in ADA Standard 1094 require compliance, those items mentioned in the Informative Annex section of the document are only suggestions and it is not mandatory to adopt these suggestions.

There are many special interest groups who propagate guidelines, practice policies, recommendations and position statements. However, strict adherence is not mandatory for these and so they offer room for professional discretion. Examples of agencies that publish guidelines, practice policies, recommendations and position statements are: The National Council on Radiation Protection and Measurements (NCRP), the ADA, the American Association of Physicists in Medicine (AAPM), the American Academy of Oral Maxillofacial Radiology (AAOMR), state and local dental associations, Image Gently, Image Wisely, and others. Also, groups such as the ADA and FDA may collaborate and release joint recommendations such as the 2012 Dental Radiographic Examinations: Recommendations for Patient Selection and Limiting Radiation Exposure which are simply good practice policies but leave room for professional discretion.[33] A further point here is although the ADA is the dental standards organization in the USA, not all publications from the ADA are standards and one must be able to differentiate and recognize the difference in compliance requirements of these ADA publications.

Statutes on the other hand are usually passed by an individual state to mandate those users of that technology, equipment or practice to comply with use terms as per state legislation. Some states have adopted the guidelines issued by special interest groups such as the NCRP, therefore mandate compliance from all the users of that technology, equipment or practice in their state. In some cases where there may be overlap or conflict between an ADA standard and the state statute, the user would be required to comply with the stricter requirement. State statutes are mandatory in that state only and failure to adhere to a state statute may result in warnings, fines, enforcement actions or a combination of these.

Many dental practitioners are confused about the role of the state radiation inspector who visits the dental facility to inspect the radiographic equipment. These are merely intended to be safety checks to ensure that the radiographic equipment is not harmful to patients and staff when x-ray equipment is utilized properly. They are not part of a radiology quality assurance program. A radiology quality assurance program involves more than checking the performance of the equipment, but also looks at image quality, personnel training and continuing education, record keeping, equipment repair records, retake log and adverse events with the radiographic equipment to identify and prevent recurrences. As mentioned earlier, the monitoring of intraoral x-ray units (i.e. generators) can be performed by dental personnel with additional training or hiring outside agencies. With the introduction of new electronic x-ray meters, the ease to perform these inspections is manageable with a small amount of radiation safety training such that any dental personnel can conduct the required tests.

Over the last number of years, some states have mailed out QA packets whereby dental offices were asked to provide a radiographic image produced with one of the x-ray generator and image receptor combination in their office for assessment of image quality. This one evaluation was assumed to be representative of all the x-ray generators throughout the dental office, which is not possible. Additionally, these mail in QA systems are ineffective as they do not reflect how the radiographic images are displayed in the dental office. Unless the reviewing facility has the exact same viewing software, computer system, display monitor, the same calibration of the viewing display monitor, the same video graphics card and the same exact setup configuration and in the same viewing environment, they cannot view the radiographic images the way they are viewed in the dental office. It is paramount that the radiographic system be calibrated and adjusted independently for the digital imaging chain in each DTR of your office by your own

personnel.. The digital radiographic system cannot be calibrated remotely like some hospital computer support systems unless all factors are controlled including the viewing environment.

Conclusion

Throughout the paper we have provided examples and scientific evidence from peer reviewed publications to disprove and nullify many of the misconceptions and myths that hamper the clinician from obtaining the maximum benefit from digital intraoral radiography. We have provided images wherever possible to help the reader visualize and appreciate the concerns.

It is hoped that the reader has gained a much greater appreciation of the need for QA in digital intraoral radiography, seeks out continuing education on dental radiology QA, and finally adopts QA processes for use in their own dental practice. At the same time, it is hoped that the reader gains a better perspective or insight and understanding of how digital intraoral radiographic systems operate to realize that without adequate QA with digital intraoral radiography, there is no telling how many diagnostic decisions may be compromised. QA is absolutely necessary and crucial to maintaining high quality diagnostic radiographs and in keeping with the radiation hygiene principle of ALARA.

Table 1.
Proposed uniformity tests along with any frequency, method and type of uniformity evaluation.

	Modality	**Frequency**	**Method**	**Uniformity Evaluation**
QUALITATIVE				
Greenall (Mar 2014)	Photostimulable storage phosphor (PSP) receptors; digital sensor	Monthly to quarterly	Capture 1 image at a fixed distance; using short exposure;	Visual inspection for areas of gross non-uniformity
The Report of AAPM Task Group 175 (Sep 2016) – dental	Digital receptors, charge-coupled devices (CCD), complementary metal oxide semiconductor (CMOS); PSP; and film	Monthly to quarterly	Follow instructions provided by phantom manufacturer	No significant non-uniformity is observed
ANSI/ADA Standard No. 1094 (Feb 2020)	Digital image acquisition device (solid state sensor; PSP and scanner)	Acceptance test and periodic checks	Blank exposure with no object; use exposure 20-40% lower than optimal; x-ray tube perpendicular to sensor plane with shortest possible source to sensor distance	May demonstrate uniform appearance
Report of AAPM Task Group 10. Report No. 93 (Oct 2006) – medical	PSP Imaging Systems	Acceptance test and periodic checks	Follow phantom manufacturer's instructions	Visualize a uniform image
QUANTITATIVE				
*Hellen Halame (May 2016)	Digital sensors based in CMOS technology	Acceptance test and periodic checks	Capture 1 flat field image using a 30 mm acrylic glass plate in front of sensor at distance to mimic clinical situation	Measure uniformity of5 circular ROIs; expressed in pixel value deviation peripherally/centrally at exposures of 0.05s and 0.16s
**Report of AAPM Task Group 10. Report No. 93 (Oct 2006) - medical	PSP Imaging Systems	Acceptance test and periodic checks	ROI over 80% of image	Average digital value of each ROI should be within 10% of global average; standard deviation should be similar in each of the 5 ROIs

*This prescribed uniformity test was unable to be performed on the Gendex GXS-700 imaging system.
**80 kVp and 5 mA exposure parameters and a distance of 180 cm from the source to image receptor was specified. Additionally, the raw data was used for assessments.

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Figures and Legends

Figure 1. An example of two types of electronic radiation meters measuring intraoral X-ray generator performance.

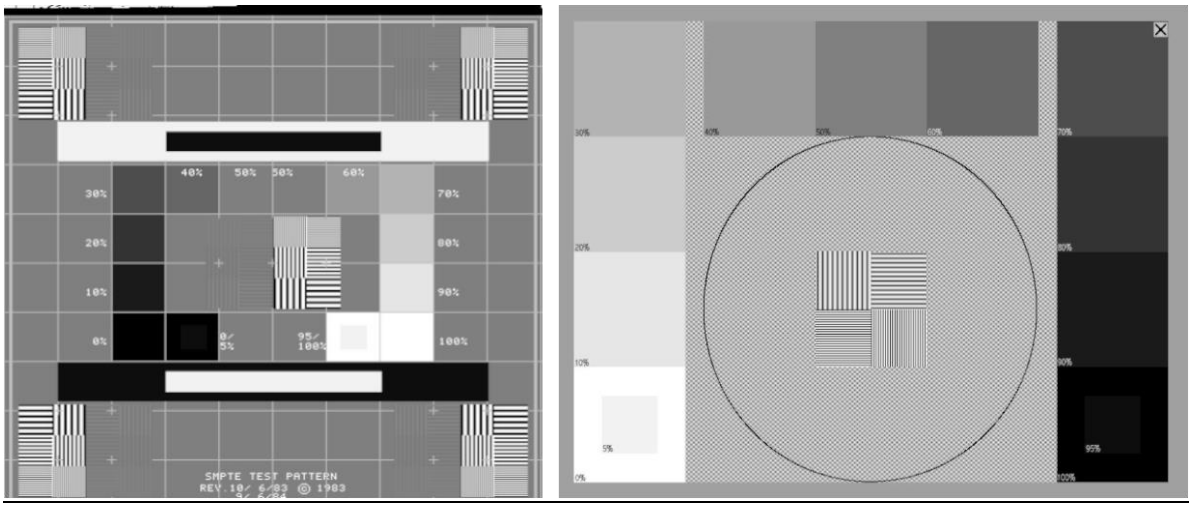

Figure 2. The image on the left is the SMPTE© Medical Viewing Monitor Calibration Test Pattern. The image on the right is a variant of the SMPTE Test Pattern provided in MiPACS Software (Medicor Imaging, Charlotte, NC).

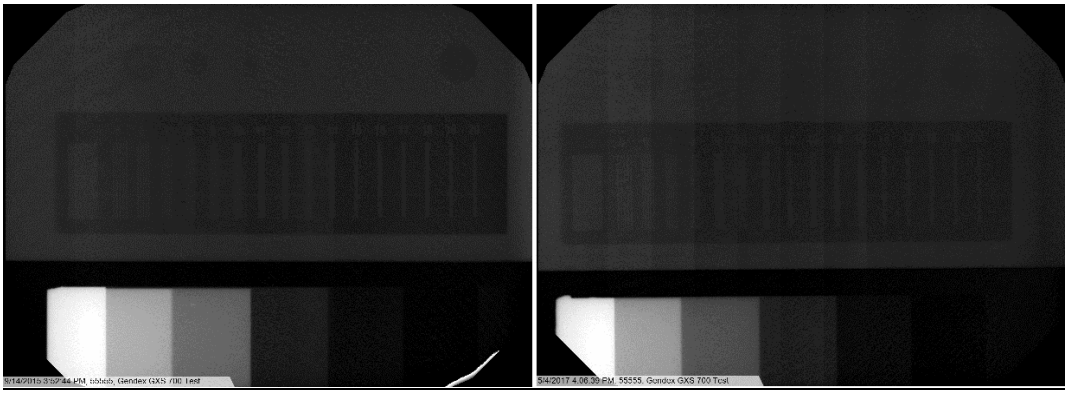

Figure 3. Image on left demonstrates delamination (uncoupling of scintillator). Image on right demonstrates non-uniformity (dark banding)

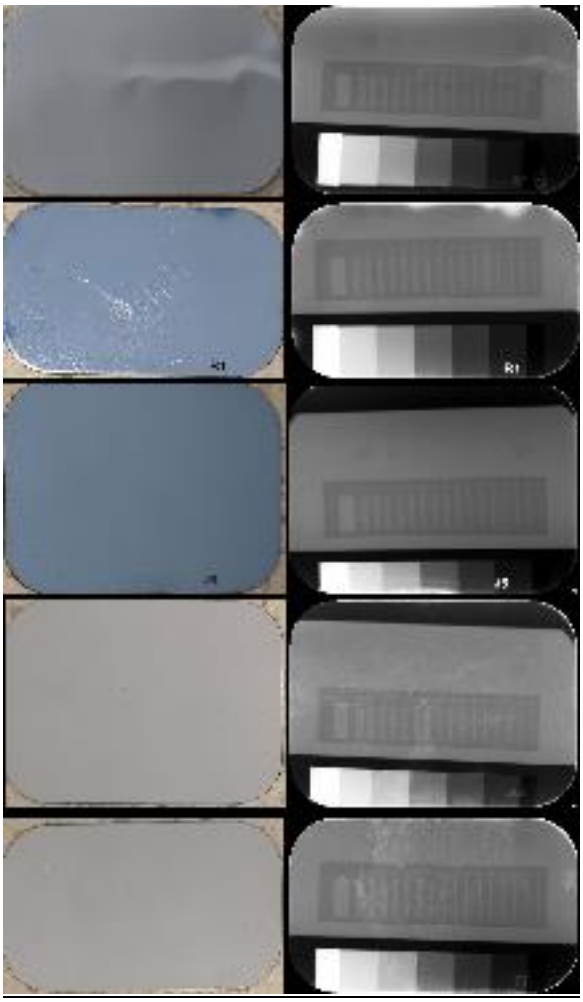

Figure 4. Damaged PSP plate images. A (top image) bite mark. B (next image) scratches and contaminated phosphor. C (middle image) separation (delamination) of phosphor at bottom of plate. D (next layer) Bent PSP plate. E (bottom layer) Bent plate, damaged/worn out phosphor

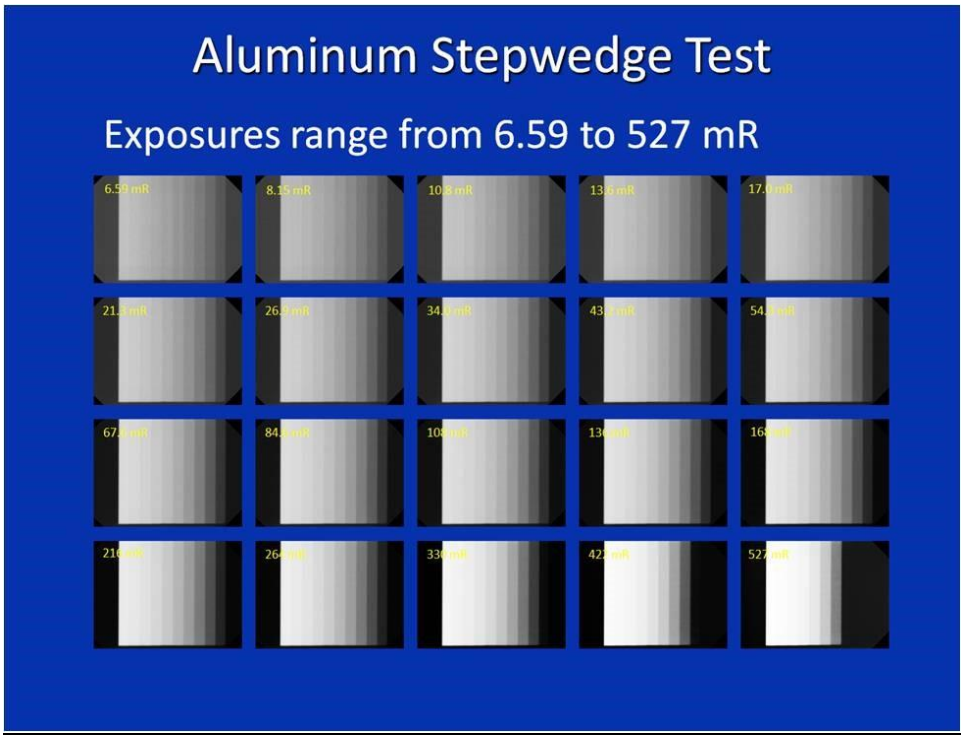

Figure 5. Series of images of an aluminum stepwedge. Note that the optimal exposure cannot be identified due to the lack of information on spatial and contrast resolutions; and lack of air and lead steps.

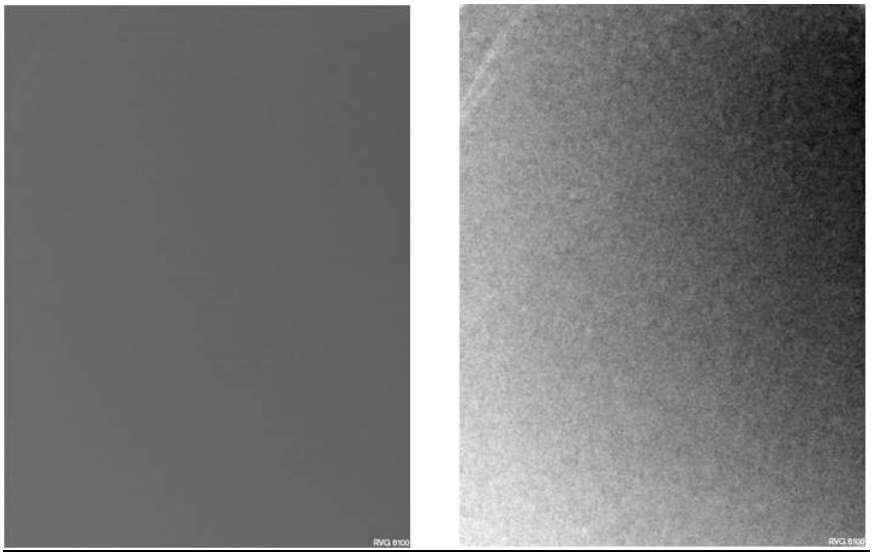

Figure 6. The image on the left is a least processed radiographic image with subtle non-uniformity. The image on the right contains added image processing resulting in severe magnification of the subtle non-uniformity.