**AAPM REPORT NO. 175** 



# Acceptance Testing and Quality Control of Dental Imaging Equipment

The Report of AAPM Task Group 175

September 2016

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# Acceptance Testing and Quality Control of Dental Imaging Equipment

# The Report of AAPM Task Group 175

Alexander L. C. Kwan<sup>1</sup> (Chair), Hung Ching<sup>2</sup> (Co-chair), Joel E. Gray<sup>3</sup>, Richard J. Massoth<sup>4</sup>, W. Doss McDavid<sup>5</sup>, Enrique Platin<sup>6</sup>, Leonard M. Rosenstein<sup>7</sup>, J. Anthony Seibert<sup>8</sup>, and Stuart C. White<sup>9</sup>

<sup>&</sup>lt;sup>1</sup>University of Alberta, Edmonton, Alberta

<sup>&</sup>lt;sup>2</sup>Memorial Sloan Kettering Cancer Center, New York, New York

<sup>&</sup>lt;sup>3</sup>Mayo Clinic College of Medicine, Emeritus Staff, Rochester, Minnesota and DIQUAD, LLC, Steger, Illinois

<sup>&</sup>lt;sup>4</sup>Medical X-Ray Center, P.C., Sioux Falls, South Dakota

<sup>&</sup>lt;sup>5</sup>University of Texas Health Science Center, San Antonio, Texas, Retired

<sup>&</sup>lt;sup>6</sup>The University of North Carolina, Chapel Hill, North Carolina

<sup>&</sup>lt;sup>7</sup>Weill Cornell Medical College, New York, New York, Retired

<sup>&</sup>lt;sup>8</sup>University of California, Davis, Sacramento, California

<sup>&</sup>lt;sup>9</sup>University of California, Los Angeles, Los Angeles, California

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## Abstract

The purpose of Task Group 175 (TG-175) is to investigate the factors that affect image quality and dose in dental units. Described herein are the recommendations for specific parameter evaluations and practical procedures that may be conducted by medical physicists on the x-ray systems associated with dental facilities.

This report is structured so that each section may be viewed as an independent chapter for the different dental modalities. Section 2 of this report provides image receptor recommendations for intraoral dental units. Sections 3, 4, and 5 provide information for the evaluation of intraoral, panoramic, and cephalometric dental units, respectively. Evaluation of cone-beam CT dental units is not included in this task group report.

The intent of this report is to provide useful information and guidance for performing acceptance testing and quality control of dental imaging equipment.

## I. Introduction

It is important to properly perform tests for image quality and safety purposes right after the installation and during routine operation of a dental x-ray unit. Having a quality control (QC) program for dental x-ray facilities is instrumental in ensuring that patients are not receiving excessive radiation during their examination. A QC program also ensures that the dental x-ray imaging equipment is working properly, as exemplified by scientific and technical testing to confirm that the machine is performing as per manufacturer's specification and regulatory requirements.

Recommendations for specific parameter evaluations and practical procedures for quality control evaluations of dental imaging equipment are described in this document. Section 2 of this report provides image receptor recommendations for intraoral dental units. Sections 3, 4, and 5 provide information for the evaluation of intraoral, panoramic, and cephalometric dental units, respectively. In addition, all methods mentioned in this report are intended to provide guidance on how to perform these medical physics tests, but they are not intended to be the sole methods for performing any particular evaluation.

While cone-beam CT (CBCT) has become common in the offices of many dental specialists, this modality falls outside the scope of this task group report. Another AAPM task group (TG-261) will be addressing CBCT for dental and maxillofacial imaging, and their report should be forthcoming.

# 2. Image Receptor Recommendations for Intraoral Dental Units

Currently, there are three types of receptor technologies available for intraoral imaging:

- 1. film (including D-, E-, E/F- and F-speed),
- 2. photostimulable storage phosphor (PSP) receptors, and
- 3. charge-coupled devices (CCD) and complementary metal oxide semiconductor (CMOS) receptors.

A discussion of the difference in the technology of the digital receptors, and information on digital radiography in general, can be found in references 1–3. There is approximately a factor of two difference in the speed, or sensitivity, of D-speed compared with E-, E/F-, or F-speed films; as a result, the E-, E/F-, or F-speed film requires only approximately half of the radiation of the D-speed film for the same image quality.<sup>4–8</sup>

Because of potential reduction in radiation without significant loss in image quality,

#### TG-175 recommends the exclusive use of E-, E/F-, or F-speed film. D-speed film should not be used.

This recommendation is in agreement with the recommendations from the National Council on Radiation Protection and Measurements (NCRP).<sup>9</sup> as well as the American Dental Association and the U.S. Food and Drug Administration.<sup>10</sup> In addition, NCRP has recently recommended a diagnostic reference level (DRL)<sup>\*</sup> of 1.6 mGy (entrance skin air kerma) for all dental intraoral imaging regardless of film speed or type of image sensor.<sup>11</sup> With D-speed film, this is insufficient to produce properly exposed dental radiographs.

Digital imaging using PSP or CCD/CMOS technology offers radiation dose reductions to dental patients and staff while providing similar or improved image quality.<sup>12–14</sup> PSP receptors require a radiation dose similar to E-, E/F-, or F-speed films, while CMOS receptors require 50% to 80% of the

<sup>\*</sup> A diagnostic reference level (DRL) represents an exposure at approximately the 75th percentile level of the distribution of survey exposures. If a facility uses exposures above the DRL, actions should be taken to optimize image quality with exposures below this level.

dose required for F-speed film, depending on the type of CMOS receptors.<sup>15</sup> Lastly, CCD receptors typically require less than half the radiation of F-speed film.<sup>15</sup>

Consequently, TG-175 recommends the use of one of the following:
1) E-, E/F-, or F-speed radiographic film,
2) PSP receptors, or
3) CCD/CMOS receptors.

# 3. Acceptance Testing and Quality Control (QC) Recommendations for Intraoral Dental Units

Recommended tests for acceptance testing and quality control of intraoral dental units are listed below. In addition, local and state regulation requirements should be reviewed to ensure all required tests are performed and their limits are met. These evaluations, with the exception of those in Section 3.10 and 3.11, should be performed or supervised by a QMP<sup>16</sup> before the unit is used clinically and annually thereafter. The QMP, who at the minimum should co-sign the final report, is ultimately responsible for all of the content. In all cases, the test results must meet the manufacturer's specifications. For older units only, where such manufacturer specifications may not be available, the standards given below should be used.

Dental handheld units are in use in the offices of general dentists and various dental specialists. The QMP may want to confirm if there are any additional requirements in state and local regulations (such as scattered radiation protection, radiation monitoring requirements, and secure storage of the x-ray unit).

#### 3.1 Tube Head Stability and Positioning (not applicable to handheld units)

Tube head drift or oscillation should stop within 1 second after the operator releases the tube head, and any drift shall be no greater than 0.5 cm, according to the NCRP.<sup>9</sup> Tube head drift should be checked to ensure compliance.

### 3.2 Leakage Radiation and Visual Inspection

Visual inspection of the tube housing should be made to ensure the radiation shielding is not damaged. If one suspects the shielding has been compromised, a leakage measurement should be performed by placing a radiation detector over the suspected location and then adjacent to it. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation, such as an integrating energy compensated detector or ion chamber, may be required. Measurements made after exposures at the two locations should be similar. Alternatively, an intraoral film or a digital sensor may be placed over the suspect area. Any spot indicating an excessive radiation exposure in the resulting image is unacceptable. Note that due to the small size of the intraoral film or digital sensor, it may be difficult to place the image receptor at the exact location of the leakage. Consequently, a larger CR plate may be used if one is available. If the shielding has, in fact, been compromised, the unit must be removed from service as soon as possible.

#### 3.3 Collimation and Minimum Source-to-Skin Distance

This check is to ensure the x-ray field size and source-to-skin distance (SSD) are within their regulatory and recommended limits. The maximum diameter of the radiation field is specified by federal regulation 21 CFR 1020.31<sup>17</sup> based on the source-to-skin distance (SSD). For SSDs of 18 cm or greater (required for units operating above 50 kVp), the maximum field size diameter at the end of the position indicating device (PID) is 7 cm. Since the task group recommends that tube voltages of less than 60 kVp should not be used (see Section 3.5 below), the minimum SSD should be no less than 18 cm. Since the collimator on the intraoral unit is fixed, one may only need to confirm this during the acceptance testing if one is confident that the collimator has not changed in the subsequent annual evaluation. The x-ray field size may be measured by exposing a film or a large CR plate (or any other image receptor) placed at the end of the PID, or any other methods that the QMP deems appropriate.

For units with rectangular collimation, the NCRP recommends the linear dimensions of the beam in each axis "*should not*<sup>\*</sup> exceed the dimension of the image receptor by more than two percent of the source-to-image receptor distance."<sup>9</sup> Due to the close tolerances between the beam and image receptor sizes, it is strongly recommended that a positioning device be used to assure complete coverage of the receptor by the x-ray beam. A variety of types are available; they are known as positioning devices, paralleling devices, film holders, or sensor holders.

#### 3.4 Beam Quality

Place a radiation detector in the x-ray beam and measure the half-value layer, in millimeters of aluminum, for the most commonly used kilovoltage. The aluminum sheets should be placed as far as possible from the radiation detector to minimize the scattered radiation detected. The minimum half-value layer should be at least that given in the manufacturer's specifications and must be in accordance with federal regulations. The current minimum requirement for HVL (half-value layer) is listed in Table 1 of 21 CFR 1020.30<sup>18</sup> and is summarized in Table 1 below. (Note: If using a solid state device with multiple sensors, all sensors should be aligned with and exposed by the beam.) If multiple kilovoltage stations are available, half-value layer measurements should be performed across the useful range of kilovoltages.

Minimum HVL (mm of Aluminum)						
X-ray Tube Potential (kVp)	Specified Dental System <sup>a</sup>	Other X-ray System <sup>b</sup>				
60	1.5	1.5				
70	1.5	1.8				
71	2.1	2.5				
80	2.3	2.9				
90	2.5	3.2				

Table 1: Minimum HVL Requirement for Intraoral Dental Units<sup>18</sup>

<sup>a</sup> Dental x-ray systems designed for use with intraoral image receptors and manufactured after December 1, 1980 <sup>b</sup> Panoramic and cephalometric systems manufactured on or after June 10, 2006.

<sup>\*</sup> From the NCRP composite glossary: "The term should (or should not) (in italics) indicates an advisory recommendation from NCRP that is to be applied when practicable or practical (e.g., cost-effective)."

## 3.5 Kilovoltage (kVp) Accuracy

Place the kilovoltage detector at a location such that all the sensors are within the exposure area of the intraoral unit. If multiple kilovoltage stations are available, make measurements across the useful range of kilovoltages. The tube voltage should be measured during the steady state period of an exposure (after the initial pre-heating), and its deviation from the nominal value must not exceed the manufacturer's specifications. In the absence of manufacturer's specifications, this deviation should not exceed 10%.

TG-175 recommends tube voltages less than 60 kVp not be used for intraoral dental imaging as this may result in higher-than-necessary patient radiation doses.

#### 3.6 Timer Accuracy

As most intraoral units contain a ramping (or preheat) period, accurate determination of the exposure time (or total number of pulses) may be difficult to determine and, therefore, is not required. Nevertheless, the QMP is encouraged to check the timer accuracy when timer settings are explicitly displayed. When tested, the deviation from the nominal timer value must not exceed the manufacturer's specifications. In the absence of manufacturer's specifications, the deviation should not exceed 10% for settings greater than 10 milliseconds.

### 3.7 Exposure Reproducibility

Place the radiation detector such that the entire sensitive volume of the radiation detector is irradiated by the primary beam. For acceptance testing, it is advisable to measure a number of technique combinations (such as maximum, typical–adult molar bitewing, and minimum exposure time). Use of the typical technique (e.g., molar bitewing) during QC testing is usually sufficient. At least three measurements at each setting should be used for determining the coefficient of variation (COV), equal to the standard deviation of the measurements divided by the mean value. The COV of the unit's air kerma (or exposure) must not exceed the manufacturer's specification. If such specification does not exist, then a maximum COV of 0.05 should be used.

### 3.8 Milliampere (mA) or Milliampere-second (mAs) Linearity

This test is intended only for x-ray units that have more than one milliampere (mA) or milliampere-seconds (mAs) station available at the same kilovoltage setting.

- 1. Measure the air kerma for each mA or mAs station across the entire clinical range at the most commonly used kilovoltage setting.
- 2. Calculate the quantity X = air kerma (mGy) / milliampere-second (mAs) for each station, where mAs refers to the set values of mA and time.
- 3. Every pair of neighboring mA (or mAs) stations must meet the following criterion<sup>17</sup>:

$$|X_1 - X_2| \le 0.10 (X_1 + X_2)$$

## 3.9 Darkroom Quality Control (If X-ray Film Is Used)

Darkroom quality control for dental film processing is essential to avoid film fog, i.e., a uniform exposure over the film, reducing contrast and perceptibility of important image details. This test determines whether image quality is being degraded by excessive fog (i.e., exposure to unwanted light).

Fog tests must be carried out for both darkrooms and processors with daylight loaders. The following describes those tests:

**Darkroom fog tests** are to be performed initially for a new darkroom and at least annually thereafter. Fog tests should also be performed each time a safelight filter or safelight bulb is changed. Other events necessitating a fog test include changes to a door, door sweep, weather-stripping, or air exchange baffle.

- 1. Ensure room lights in adjacent rooms are turned on. Also, confirm the film processor is turned on and operating at the proper temperature.
- 2. Turn off all room and safelights in the darkroom. Wait three to five minutes for your eyes to adapt to the darkness. Look for and eliminate any sources of light from doors, ventilation sources, exhausts, and indicator lights on the processor or timer. (Black electrical tape works well for small leaks.) Turn the safelights back on.
- 3. In the darkroom, remove the film from the packet. Place it on the work counter and cover one half of it with thin, opaque material.
- 4. Stand back from the counter so as not to cast a shadow on the film.
- 5. Leave the film on the work counter for two minutes and then process it.
- 6. After placing the film on a viewbox, use a pen or pencil to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive darkroom fog that comes from a light leak must be eliminated.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., a pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 7. If a density difference is visible, it may be due to
  - a. the wattage of the safelight bulb may be too high,
  - b. the safelight may be too close to the counter,
  - c. the safelight filter may be faded, damaged, or incorrect,
  - d. there may be too many safelights in the darkroom, or
  - e. there may be leakage of outside light into the room.

If one suspects the fog is due to the safelights (items a to d), one should repeat the test with the safelights turned off to confirm this.

**Daylight loader fog tests** are to be performed initially for a new daylight loading processor and at least annually thereafter. Fog tests should also be performed each time any lighting in the room is changed, e.g., light bulbs are replaced. In addition, a fog test should be performed any time changes are made to the daylight loader.

- 1. Place the film packet in the daylight loader, remove the film from the packet, and cover one half of it with thin, opaque material.
- 2. Stand back from the counter so as not to cast a shadow on the daylight loader.
- 3. Leave the film for two minutes and then process the film.
- 4. After placing the film on a viewbox, use a pen or pencil to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive light is entering the

daylight loader.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., a pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 5. If a density difference is visible, it may be due to
  - a. a change in the daylight loader filter,
  - b. room lights may be too bright,
  - c. the daylight loader filter may be cracked, faded, damaged, or incorrect, or
  - d. the material in the ports of the daylight loader (where one places hands to access the inside of the daylight loader) may be worn, cracked, or some pieces may be missing.

### 3.10 Film Processing Quality Control for Intraoral Film

Film processing quality control is essential to ensure proper film processing. Improper film processing results in decreased image contrast (ability to perceive small density differences) and may also result in increased radiation dose to patients and staff. Optimized film processing also results in fewer film retakes.

To ensure the optimal function of the photographic processing chemicals and processing equipment (manual or automatic), film processing QC should be carried out for both manual and automatic processing once each day before developing any patient films. The daily test should be performed by the personnel on site and reviewed by the QMP during the evaluation of the site's QC program.

For film QC, the Crabtree device, marketed under the name "Dental Radiographic Quality Control Device," provides a method for determining the appropriate exposure for dental film and provides the means to carry out film processor quality control. The Conference of Radiation Control Program Directors, Inc. (CRCPD) also provides an alternative method for performing film processing quality control. While the CRCPD's method does not utilize any commercial QC tool, it requires the use of a sensitometer and a densitometer. Information about this method can be found in Procedure B in Appendix B of Reference 19. If a panoramic or cephalometric unit is used, the film processing QC must be performed using a sensitometer and densitometer.

### 3.11 Quality Control for Digital Intraoral Image Receptors

In digital radiography, quality control is essential to ensure proper image quality. Because of the extended dynamic range of digital detector response and subsequent image processing, underexposures may result in the loss of ability to perceive small density differences due to excessive quantum noise. Conversely, overexposures may result in increased radiation dose to patients and staff.

Quality control for digital radiography ensures optimal system functionality and image quality. QC should be carried out at regular intervals (daily, weekly, or monthly, depending on the office) and whenever sensors are suspected to be damaged or are replaced. Table 1 in Reference 20 also provides a suggested evaluation frequency for digital receptor QC checks. The test should be performed by the personnel on site and the results reviewed by the QMP during the evaluation of the site's QC program.

#### 3.11.1 Equipment Needed

Currently there is no standard method for evaluating the image quality of digital intraoral x-ray units. Nevertheless, evaluation of image quality with a phantom should be performed if the manufac-

<sup>\*</sup> Direct exposure x-ray film cannot be used for quality control of screen-film systems such as the panoramic and cephalometric systems due to the differences in spectral and processing sensitivity exhibited by the different film types.

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turer does not provide the quality control information. The image quality parameters to be evaluated should include, but not be limited to, uniformity, contrast resolution, and spatial resolution.

A limited number of commercially available QC tools are available. Two examples for digital dental QC are the Digital Dental Quality Assurance (DDQA<sup>\*</sup>) phantom<sup>15,21,22</sup> and the TOR DEN phantom.<sup>20</sup> According to the manufacturer, the latter phantom can be used for the evaluation of intraoral, panoramic, and cephalometric systems.<sup>†</sup> The TOR DEN phantom is also marketed under other names.

#### 3.11.2 Initial Evaluation

Prior to carrying out the uniformity and artifact evaluations, one should verify that the display used to evaluate the phantom image(s) is functioning properly. (One may also want to confirm that all the other display(s) on site used to evaluate the clinical images are functioning properly.) This may be done by using test patterns such as the Society for Motion Picture and Television Engineers (SMPTE) Medical Diagnostic Imaging Test Pattern<sup>23,24</sup> (Figure 1a), TG18-QC pattern<sup>25</sup> (Figure 1b), or equivalent.

For the SMPTE pattern, the window width should be set to encompass the entire range of pixel values in the test pattern. The window level is set at the middle of the window width or the lowest value of the window width, depending on the system being used.

For the DICOM and the 16-bit TIFF format TG18-QC patterns, the window width should be set to encompass the range from 0 to 4095.<sup>‡</sup> The window level is set at either the center or the lower end of the window width, depending on the system being tested.

For either test pattern, the overall image should be inspected to ensure the absence of gross artifacts, such as blurring or bleeding of bright display areas into dark areas. All the gray levels should be visible, and both the 5% and the 95% areas should be seen as distinct from the adjacent 0% and 100% areas. Brightness and contrast should be adjusted until these conditions are met. A detailed discussion of the TG18-QC pattern can be found in Section 4 of the AAPM Online Report No. 3.<sup>25</sup>

Prior to the initial evaluation, one should also confirm that images produced by the PSP or CCD/ CMOS receptors are free from artifacts using a non-saturated, uniform exposure (flat field image).

The PSP receptor reader (when applicable) should be set up as per the manufacturer's recommendation. A detailed discussion of acceptance and QC evaluation of PSP systems can be found in Sections 8–10 of the AAPM Report No. 93.<sup>26</sup>

Follow the instructions provided by the phantom manufacturer, and record the required baseline information, such as the standard exposure technique and the resulting image quality information, which may include, but not be limited to, uniformity (monthly to quarterly), contrast resolution (quarterly to semi-annually), and spatial resolution (quarterly to semi-annually), as suggested by Reference 20.

<sup>\*</sup> Dr. McDavid, a member of TG-175, is one of the inventors of the DDQA phantom (US Patent # 8,308,362) and one of the partners in Dental Imaging Consultants LLC (San Antonio, TX), the company that sells the DDQA phantom.

<sup>†</sup> TG-175 has no direct experience with this phantom. It is well known, however, that a meaningful measurement of spatial resolution in panoramic radiography would require positioning the resolution pattern in the central plane of the image layer. This may be difficult to achieve in the average dental clinic.

<sup>‡</sup> Care should be taken to ensure the test pattern used matches the specification of the system being evaluated. For example if an 8-bit system is being evaluated, the 8-bit test pattern should be used to evaluate the system. Appendix III in Reference 25 provides a detailed description of the TG18-QC pattern in order to generate the required test pattern (such as the 8-bit version).

#### 3.11.3 Periodic Quality Control Testing

Evaluation of the QC phantom images should be carried out at regular intervals (daily, weekly, biweekly, or monthly) as recommended by the QMP to verify sensor performance. It is strongly recommended that a quality control evaluation be performed if the sensor has been dropped, mishandled, or bitten by a patient.

It is also recommended that the monitor performance and image artifact evaluation on the image receptor (PSP or CCD/CMOS receptors) be carried out at a regular interval as recommended by the QMP. Lastly, because PSP receptors accumulate signals from background radiation over time, they should be erased prior to use if they are not frequently used. In addition, the location of the PSP receptor storage should be away from any ionizing radiation source.

#### 3.12 Evaluation of Site's Quality Control Program

The QMP should evaluate the site's QC procedures and results annually. This should include a review of the QC activities performed by personnel on site, as well as the service history of the equipment.

#### 3.13 Technique Factors and Entrance Skin Air Kerma

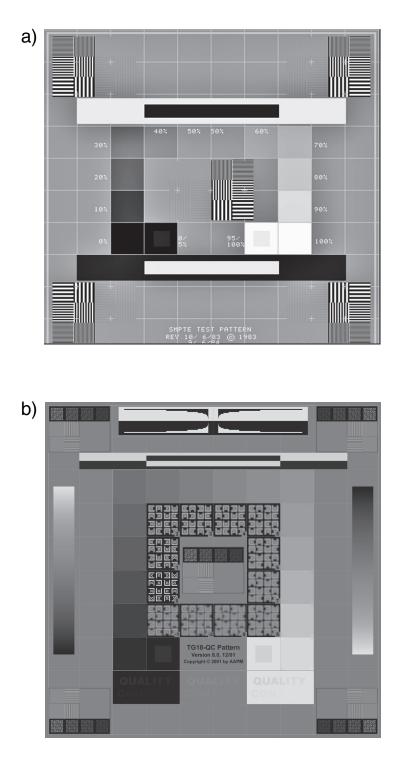
For each intraoral unit, the entrance skin air kerma or entrance skin exposure shall be measured using the facility's clinical technique factors for the most common projection (e.g., posterior bitewing radiograph) and compared to appropriate DRLs and achievable doses. The exposure settings used should be consistent with the manufacturer's recommendations for the digital sensors (or film). Techniques resulting in a lower patient dose may be used if they maintain the necessary image quality. A technique chart should be posted next to the operator control panel. NCRP<sup>11</sup> recommends a diagnostic reference level (DRL) of 1.6 mGy (entrance skin air kerma) for all dental intraoral imaging regardless of film speed or type of image sensor.

### 3.14 Scattered Radiation Survey

During the acceptance testing of the intraoral units, one may also want to perform a scattered radiation survey. This can be done by exposing a head phantom or a one-gallon milk jug filled with water using the typical clinical protocol and measuring the resulting scattered radiation at location(s) where the site's personnel are likely to be located, e.g., near the control panel. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation (in the 9 to 90 nGy or 1 to 10  $\mu$ R range) is recommended. It is advisable to use an instrument that is capable of operating in integrate mode and measure the scattered x-ray for the exposure. The use of the rate mode is impractical for exposures of short duration. An integrating energy-compensated solid state detector or integrating ion chamber is a good instrument choice.

Refer to Table 2 for a summary of acceptance and QC recommendations for intraoral, panoramic, and cephalometric dental units.

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**Figure 1.** Test patterns for display evaluation. a) SMPTE pattern with 5% and 95% patches indicated by the arrows. (SMPTE test pattern courtesy of the Society of Motion Picture and Television Engineers, www.smpte.org. Reprinted with permission. b) The TG18-QC pattern. (From AAPM on-line Report No. 03, Assessment of display performance for medical imaging systems. College Park, MD: AAPM, 2005. Reprinted with permission.)

# 4. Acceptance Testing and Quality Control Recommendations for Panoramic Dental Units

Recommended tests for acceptance testing and quality control of panoramic dental units are listed below. In addition, local and state regulation requirements should be reviewed to ensure all required tests are performed and the their limits are met. These evaluations should be performed or supervised by a Qualified Medical Physicist (QMP)16 before the unit is used clinically and annually thereafter. The QMP, who at the minimum should co-sign the final report, is ultimately responsible for all of the content. In all cases, the test results must meet the manufacturer's specifications. For older units only, where such manufacturer specifications may not be available, the standards given below should be used.

#### 4.1 Leakage Radiation and Visual Inspection

Visual inspection of the tube housing should be made to ensure the radiation shielding is not damaged. If one suspects the shielding has been compromised, a leakage measurement should be performed by placing a radiation detector over the suspected location and then adjacent to it. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation, such as an integrating energy compensated detector or ion chamber, may be required. Measurements made after exposures at the two locations should be similar. Alternatively, an intraoral film or a digital sensor may be placed over the suspect area. Any spot indicating an excessive radiation exposure in the resulting image is unacceptable. Note that due to the small size of the intraoral film or digital sensor, it may be difficult to place the image receptor at the exact location of the leakage. Consequently, a larger CR plate may be used if one is available. If the shielding has, in fact, been compromised, the unit must be removed from service as soon as possible.

## 4.2 X-ray Beam Slit Length and Width Coincidence

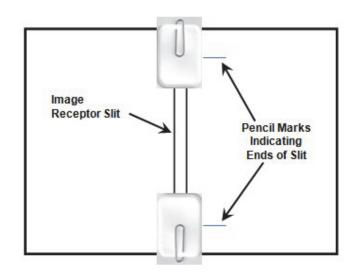
The following is one possible procedure that can be used to determine if the length of the x-ray field (vertical dimension) extends beyond the image receptor and if the width of the x-ray field (horizontal dimension) is within the specified tolerance for units with an x-ray beam slit near the image receptor:

- 1. Place a paper clip on each of two intraoral films, PSP receptors, or radiochromic films<sup>\*</sup> so the length of the paper clip is parallel with and centered on the length of the receptors.
- 2. Ensure that one end of the paper clip is at the center of the receptor (Figure 2). Place pencil marks adjacent to the ends of the slit on the front of the image receptor, indicating the top and bottom of the slit.
- 3. Place each packet and paper clip on the image receptor so they are aligned with the slit or the line indicating the slit location on the image receptor. Assure that the ends of the paper clips in the center of the receptors are aligned with the pencil marks indicating the ends of the slit (Figure 3).
- 4. Expose the receptors by making a conventional panoramic exposure and then process the receptors accordingly for viewing.

An alternative method is to replace the intraoral film packet (or PSP receptor) with fluorescent material (screen). The screen is set up similar to Steps 1 to 3 above, and a video camera (e.g., a smart phone) is used to record the fluorescent slit images produced during the exposure (Step 4). A smaller

<sup>\*</sup> Multiple exposures may be required to exposure the radiochromic film properly as indicated in Reference 27.





**Figure 2.** Intraoral film packet with paper clip.

**Figure 3.** Image receptor cover showing intraoral packets with paper clips. Note: a PSP receptor may be used for digital facilities in a similar manner. In addition, a large CR plate or radiochromic film may also be used, if available.

video camera may be taped securely onto the tube side of the panoramic unit pointing directly at the image receptor to avoid any movement issues. The resulting video can be analyzed using criteria discussed in Step 5.

Since there are no standard criteria for this test at this time, the results should be determined by the QMP based on the manufacturer's specifications, state regulation, or any future internationally recognized standard (e.g., IEC). Due to difficulties in precisely placing the films, PSP detectors, paper clips, fluorescent materials, etc., the following are suggested as acceptance criteria:

- a. The x-ray field should be congruent with the sensitive area of the image receptor, including the width and alignment, and be contained within the beam slit (when the slit is provided) in the width direction and within 2% of the SID total error in the vertical direction with respect to the slit (when provided).
- b. The x-ray field should not exceed the sensitive area of the image receptor along the long dimension.

#### 4.3 Beam Quality

Place a radiation detector in the x-ray beam (e.g., near the location of the chin support) and measure the half-value layer in millimeters of aluminum for the most commonly used kilovoltage. The aluminum sheets should be placed as far as possible from the radiation detector, preferably directly on the front of the collimator housing. The minimum half-value layer should be at least that given in the manufacturer's specifications and must be in accordance with federal regulations. Table I in Section 3.4 shows selected minimum HVL requirements for panoramic and cephalometric systems. (Note: If using a solid state device with multiple sensors, all sensors should be aligned with and exposed by the beam.)

# 4.4 Kilovoltage Accuracy\*

Place a kilovoltage detector at a location along the central axis of the radiation beam. Since the panoramic unit uses a scanning slit radiation beam, it may be necessary to attach the kilovoltage sensor to the moving detector so it will be in the beam for the entire exposure. Be careful to ensure that the ear and nasal positioning devices are not in the beam. Make exposures across the useful range of kilovoltages, at a minimum including the lowest, highest, and central kilovoltages. All units must meet the manufacturer's specifications. Older units, without manufacturer's specifications, should be accurate to within  $\pm 10\%$ .

#### 4.5 Exposure Reproducibility

Place the radiation detector in the primary beam path. Bear in mind that if the entire sensitive volume of the radiation detector is generally NOT irradiated by the primary beam, the position of the radiation detector has to be exact between the different exposures to ensure the reproducibility of the measurements. One possible method is to tape a pencil (CT) chamber in front of the slot of the panoramic units. In this setup, the length of the CT chamber must be aligned with respect to the vertical dimension of the x-ray beam. Also, care should be taken to ensure that the cable does not get caught in the rotating gantry and the motion does not lead to excessive noise measurement in the reading.

For acceptance testing, it is advisable to measure a number of technique combinations. Use of the typical technique during QC testing is usually sufficient. At least three measurements at each setting should be used for determining the coefficient of variation (COV), equal to the standard deviation of the measurements divided by the mean value. The COV of the unit's air kerma (or exposure) must not exceed the manufacturer's specification. If such specification does not exist, then a maximum COV of 0.05 should be used.<sup>†</sup>

### 4.6 Darkroom Quality Control (If X-ray Film Is Used)

This test determines whether image quality is being degraded by excessive darkroom fog (i.e., exposure to unwanted light). Due to the differences in the spectral and processing sensitivities between the intraoral and the panoramic films, one must test the darkroom or the daylight loader using the film(s) that it is designed to process.

Fog tests must be carried out for both darkrooms and processors with daylight loaders. The following describes those tests:

**Darkroom fog tests** are to be performed initially for a new darkroom and at least annually thereafter. Fog tests should also be performed each time a safelight filter or safelight bulb is changed. Other events necessitating a fog test include changes to a door, door sweep, weather-stripping, or air exchange baffle.

- 1. Ensure room lights in adjacent rooms are turned on. Also, confirm the film processor is turned on and operating at the proper temperature.
- 2. Turn off all room and safelights in the darkroom. Wait three to five minutes for your eyes to adapt to the darkness. Look for and eliminate any sources of light from doors, ventilation sources, exhausts, and indicator lights on the processor or timer. (Black electrical tape works well for small leaks.) Turn the safelights back on.

<sup>\*</sup> This test is recommended, but may not always be possible, depending on the characteristics of the test equipment being used.

<sup>&</sup>lt;sup>†</sup> Some older panoramic units may not be able to meet the 0.05 requirement, and a larger tolerance (such as 0.10) may be needed.

- 3. Expose a panoramic film in a cassette with x-rays to an optical density of approximately 1.00 (i.e., medium gray density when developed). Panoramic film must be pre-exposed since it takes, on average, three photon hits to make a silver grain developable. This is due the fact that the film-based panoramic systems use a screen-film setup instead of direct film exposure (no screen) for the film-based intraoral systems. In this case, a light fog exposure might not be apparent on an unexposed film, but this additional exposure to pre-exposed film would show fog. In contrast, for intraoral film, a one photon hit makes many grains developable. Hence, the exposure for the fog test will not make a difference.
- 4. In the darkroom, remove the film from the cassette, place it on the work counter, and cover one half of it with thin, opaque material.
- 5. Stand back from the counter so as not to cast a shadow on the film.
- 6. Leave the film on the work counter for two minutes and then process it.
- 7. After placing the film on a viewbox, use a pen or pencil to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive darkroom fog that comes from a light leak must be eliminated.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 8. If a density difference is visible, it may be due to
  - a. the wattage of the safelight bulb may be too high,
  - b. the safelight may be too close to the counter,
  - c. the safelight filter may be faded, damaged, or incorrect,
  - d. there may be too many safelights in the darkroom, or
  - e. there may be leakage of outside light into the room.

If one suspects the fog is due to the safelights (items a to d), one should repeat the test with the safelights turned off to confirm this.

**Daylight loader fog tests** are to be performed initially for a new daylight loading processor and at least annually thereafter. Fog tests should also be performed each time any lighting in the room is changed, e.g., light bulbs are replaced. In addition, a fog test should be performed any time changes are made to the daylight loader.

- 1. Expose a panoramic film in a cassette with x-rays to an optical density of approximately 1.00 (i.e., medium gray density when developed). Panoramic film must be pre-exposed since it takes, on average, three photon hits to make a silver grain developable. This is due the fact that the film-based panoramic systems use a screen-film setup instead of direct film exposure (no screen) for the film-based intraoral systems. In this case, a light fog exposure might not be apparent on an unexposed film, but this additional exposure to pre-exposed film would show fog. In contrast, for intraoral film, a one photon hit makes many grains developable. Hence, the exposure for the fog test will not make a difference.
- 2. Place the film cassette in the daylight loader, remove the film from the cassette, and cover one half of it with thin, opaque material.
- 3. Stand back from the counter so as not to cast a shadow on the daylight loader.
- 4. Leave the film for two minutes and then process the film.

5. After placing the film on a viewbox, use a pen or pencil to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive light is entering the daylight loader.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., a pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 6. If a density difference is visible, it may be due to
  - a. a change in the daylight loader filter,
  - b. room lights may be too bright,
  - c. the daylight loader filter may be cracked, faded, damaged, or incorrect, or
  - d. the material in the ports of the daylight loader (where one places hands to access the inside of the daylight loader) may be worn, cracked, or some pieces may be missing.

#### 4.7 Quality Control for Digital Panoramic Image Receptors

In digital radiography, quality control is essential to ensure proper image quality. Because of the extended dynamic range of digital detector response and subsequent image processing, underexposures may result in the loss of ability to perceive small density differences due to excessive quantum noise. Conversely, higher-than-optimum exposures will result in increased radiation dose to patients and staff.

Quality control for digital panoramic radiography ensures optimal system functionality and image quality. QC should be carried out at regular intervals and whenever sensors are suspected to be damaged or are replaced. Table 1 in Reference 20 suggests uniformity evaluation should be performed on a monthly to quarterly interval. In addition, an artifact evaluation should also be performed at the same time. The test should be performed by the personnel on site and the results reviewed by the QMP during the evaluation of the site's QC program.

Currently there is no standard method for evaluating the image quality of panoramic x-ray units. Consequently, one should follow the manufacturer's recommendations if available.

Prior to carrying out the uniformity and artifact evaluations, one should verify that the display used to evaluate the phantom image(s) is functioning properly. (One may also want to confirm that all the other display(s) on-site used to evaluate the clinical images are functioning properly.) This may be done by using test patterns such as the Society for Motion Picture and Television Engineers (SMPTE) Medical Diagnostic Imaging Test Pattern<sup>23,24</sup> (Figure 1a), TG18-QC pattern<sup>25</sup> (Figure 1b), or equivalent.

For the SMPTE pattern, the window width should be set to encompass the entire range of pixel values in the test pattern. The window level is set at the middle of the window width or the lowest value of the window width, depending on the system being used.

For the DICOM and the 16-bit TIFF format TG18-QC patterns, the window width should be set to encompass the range from 0 to 4095.<sup>\*</sup> The window level is set at either the center or the lower end of the window width, depending on the system being tested.

For either test pattern, the overall image should be inspected to ensure the absence of gross artifacts, such as blurring or bleeding of bright display areas into dark areas. All the gray levels should be

<sup>\*</sup> Care should be taken to ensure the test pattern used matches the specification of the system being evaluated. For example if an 8-bit system is being evaluated, the 8-bit test pattern should be used to evaluate the system. Appendix III in Reference 25 provides a detailed description of the TG18-QC pattern in order to generate the required test pattern (such as the 8-bit version).

visible, and both the 5% and the 95% areas should be seen as distinct from the adjacent 0% and 100% areas. Brightness and contrast should be adjusted until these conditions are met. A detailed discussion of the TG18-QC pattern can be found in Section 4 of the AAPM Online Report No.  $3.^{25}$ 

#### 4.8 Technique Factors

The exposure settings used should be consistent with the equipment (or film) manufacturer's recommendations. Techniques resulting in a lower patient dose may be used if they maintain the necessary image quality. A technique chart should be posted next to the operator control panel.

NCRP Report No. 172 recommends a diagnostic reference level of 100 mGy cm<sup>2</sup> for the air kerma-area product, and an achievable dose-area product<sup>\*</sup> of 76 mGy cm<sup>2</sup> for panoramic radiography.<sup>11</sup> Note: The air kerma-area product is displayed on some newer systems. For any QMP who is interested in verifying the air kerma-area product value, one possible method is discussed in the HPA-CRCE-032 report.<sup>28</sup>

### 4.9 Evaluation of Site's Quality Control Program

The QMP should evaluate the site's QC procedures and results annually. This should include a review of the QC activities performed by personnel on site, as well as the service history of the equipment.

#### 4.10 Scattered Radiation Survey

During the acceptance testing of the intraoral units, one may also want to perform a scattered radiation survey. This can be done by exposing a head phantom or a one-gallon milk jug filled with water using the typical clinical protocol and measuring the resulting scattered radiation at location(s) where the site's personnel are likely to be located, e.g., near the control panel. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation (in the 9 to 90 nGy or 1 to 10  $\mu$ R range) is recommended. It is advisable to use an instrument that is capable of operating in integrate mode and measure the scattered x-ray for the exposure. The use of the rate mode is impractical for exposures of short duration. An integrating energy-compensated solid state detector or integrating ion chamber is a good instrument choice.

Refer to Table 2 for a summary of acceptance and QC recommendations for intraoral, panoramic, and cephalometric dental units.

# 5. Acceptance Testing and Quality Control Recommendations for Cephalometric Dental Units

Recommended tests for acceptance testing and quality control of cephalometric dental units are listed below. In addition, local and state regulation requirements should be reviewed to ensure all required tests are performed and their limits are met. These evaluations should be performed or supervised by a Qualified Medical Physicist (QMP)<sup>16</sup> before the unit is used clinically and annually thereafter. The QMP, who at the minimum should co-sign the final report, is ultimately responsible for all of the content. In all cases, the test results must meet the manufacturer's specifications. For older units only, where such manufacturer specifications may not be available, the standards given below should be used.

<sup>\*</sup> An achievable dose is one which should be a target for optimized image quality and patient dose. It is set at about the 50<sup>th</sup> percentile of the dose survey.

## 5.1 Leakage Radiation and Visual Inspection

Visual inspection of the tube housing should be made to ensure the radiation shielding is not damaged. If one suspects the shielding has been compromised, a leakage measurement should be performed by placing a radiation detector over the suspected location and then adjacent to it. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation, such as an integrating energy compensated detector or ion chamber, may be required. Measurements made after exposures at the two locations should be similar. Alternatively, an intraoral film or a digital sensor may be placed over the suspect area. Any spot indicating an excessive radiation exposure in the resulting image is unacceptable. Note that due to the small size of the intraoral film or digital sensor, it may be difficult to place the image receptor at the exact location of the leakage. Consequently, a larger CR plate may be used, if available. If the shielding has, in fact, been compromised, the unit must be removed from service as soon as possible.

#### 5.2 Collimation

For scanning slit systems, please refer to the "X-ray Beam Slit Length and Width Coincidence" section (Section 4.2) of the procedure for panoramic units. Note that this test must be performed separately for both panoramic and cephalometric modes.

For broad-beam units, manually adjust the field size or select an aperture to ensure the entire radiation field falls within the image receptor. Set the size exactly to an easily read value on the field size indicator (if so equipped), such as  $8 \times 10$  inches.

If a light field is available, turn on the field light and tape five coins to the face of the image receptor, within the light field. Place one coin at the center of each side with its outer edge just touching the edge of the light field. Place the fifth coin in one of the quadrants to indicate image orientation. Make an exposure at a low kilovoltage (kVp) and milliampere-second (mAs) technique and process the image.

To check the light-radiation field coincidence, measure the distance from the outer edge of each coin to its corresponding radiation field edge. The sum of the discrepancies (disregarding the sign of the value) of opposing light and radiation field edges must not exceed 2% of the source-to-image distance (SID).

To determine the field size indicator accuracy, measure the width and height of the radiation field. Each dimension of the radiation field must agree with the corresponding indicator setting to within 2% of the SID.

To check the radiation field and image receptor alignment, draw diagonal lines on the image between opposing corners of the radiation field, and do similarly for the entire image receptor (e.g., the film). Measure the distance between the intersections of the two sets of diagonal lines. This distance must be no more than 2% of the SID.

### 5.3 Exposure Reproducibility, Typical Entrance Air Kerma, and Technique Factors

Place the radiation detector at beam center on one of the ear positioning devices. Alternatively, the radiation detector may also be located at the center of the head position. Either way, one must ensure that the entire sensitive volume of the radiation detector is irradiated by the primary beam in order to perform the entrance air kerma calculation discussed in the following paragraph. Commonly used adult and pediatric technique should be measured, and at least three measurements for each technique should be measured to for determining the coefficient of variation (COV), equal to the standard deviation of the measurements divided by the mean value. The COV of the unit's air kerma (or exposure) must not exceed the manufacturer's specification. If such specification does not exist, then a maximum COV of 0.05 should be used.

The NCRP Report No. 172, Section 6.4.2.3,<sup>11</sup> "recommends adopting the Michigan 85<sup>th</sup> percentile entrance skin dose" (0.14 mGy) and the median dose (0.09 mGy) as the diagnostic reference level (DRL) entrance skin dose and the achievable dose, respectively.<sup>\*</sup> Using the averaged air kerma measurement from the previous paragraph, calculate and record the entrance air kerma for the most commonly used adult and pediatric techniques. Note that the Michigan's cephalometric radiography survey is similar to the 1999 NEXT dental survey for cephalometric imaging procedure (Appendix B of Reference 29),<sup>†</sup> which defines the entrance skin location as 17.5 cm from the image:

$$ESAK = \overline{K_a} \times \left[ SDD / \left( SID - 17.5 \right) \right]^2$$

Here *ESAK* is the entrance skin air kerma,  $\overline{K_a}$  is the averaged air kerma measured previously, *SDD* is the source-to-(radiation) detector distance (in cm), and the *SID* is the source-to-image distance (in cm).

Alternatively, if the air kerma-area product is available (displayed on some newer systems), NCRP recommends a diagnostic reference level of 32.6 mGy cm<sup>2</sup> for adults, and an air kerma-area product of 17 mGy cm<sup>2</sup> for achievable dose.<sup>11</sup> For children, the recommended diagnostic reference level and achievable dose are 26.4 and 14 mGy cm<sup>2</sup>, respectively.

The exposure settings used should be consistent with the digital sensor (or film) manufacturer's recommendations. Techniques resulting in a lower patient dose may be used if they maintain the necessary image quality. A technique chart should be posted next to the operator control panel.

#### 5.4 Beam Quality

Using the same setup as for the Exposure Reproducibility test, measure the half-value layer in millimeters of aluminum for the most commonly used kilovoltage. The aluminum sheets should be placed as far as possible from the radiation detector, preferably directly in front of the collimator housing. If possible, the field size at the detector should be only slightly larger than the detector itself. The minimum half-value layer should be at least that in the manufacturer's specifications and must be in accordance with federal regulations (see Table 1 in Section 3.4).

#### 5.5 Kilovoltage Accuracy

Place the kilovoltage detector at a location along the central axis of the radiation beam. If the x-ray unit uses a scanning slit radiation beam, it may be necessary to attach the kilovoltage sensor to the moving detector so it will be in, and aligned with, the beam for the entire exposure. Be careful to ensure that the ear and nasal positioning devices are not in the beam. Make exposures across the useful range of kilovoltages, at a minimum including the lowest, highest and central kilovoltages. All units must meet the manufacturer's specifications. Older units, without manufacturer's specifications, should be accurate to within  $\pm 10\%$ .

### 5.6 Milliampere (mA) or Milliampere-second (mAs) Linearity (if applicable)

This test is intended only for x-ray units that have more than one milliampere (mA) or milliampere-seconds (mAs) station available at the same kilovoltage setting.

<sup>\*</sup> If exposure measurements are displayed in milliroentgens, calculate the air kerma in milligrays by multiplying the exposure by 0.00876 mGy/mR.

<sup>†</sup> TG-175 would like to thank Bruce Matkovich from the Radiation Safety Section of the Department of Licensing and Regulatory Affairs in Michigan for confirming the measurement protocol used in the Michigan State cephalometric radiography survey.

- 1. Measure the air kerma for each mA or mAs station across the entire clinical range at the most commonly used kilovoltage setting.
- 2. Calculate the quantity X = air kerma (mGy) / milliampere-second (mAs) for each station, where mAs refers to the set values of mA and time.
- 3. Every pair of neighboring mA (or mAs) stations must meet the following criterion<sup>17</sup>:

$$|X_1 - X_2| \le 0.10 (X_1 + X_2)$$

#### 5.7 Timer Accuracy (If Applicable)

This test should be performed only if the x-ray unit has explicit, variable settings for the exposure time. With the detector in the radiation beam, make exposure measurements across the useful range of the timer, including, at least, the useful maximum, minimum, and central values. The accuracy of each time measurement must be within the manufacturer's specifications. Older units, without manufacturer's specifications, should be accurate to within 10% for settings greater than 10 milliseconds. If the generator output radiation is pulsed, the timer accuracy should be within 1 pulse.

#### 5.8 Darkroom Quality Control (If X-ray Film Is Used)

This test determines whether image quality is being degraded by excessive darkroom fog (i.e., exposure to unwanted light). Due to the differences in the spectral and processing sensitivities between the intraoral and the cephalometric films, one must test the darkroom or the daylight loader using the film(s) that it is designed to process.

Fog tests must be carried out for both darkrooms and processors with daylight loaders. The following describes those tests:

**Darkroom fog tests** are to be performed initially for a new darkroom and at least annually thereafter. Fog tests should also be performed each time a safelight filter or safelight bulb is changed. Other events necessitating a fog test include changes to a door, door sweep, weather-striping, or air exchange baffle.

- 1. Ensure room lights in adjacent rooms are turned on. Also, confirm the film processor is turned on and operating at the proper temperature.
- 2. Turn off all room and safelights in the darkroom. Wait three to five minutes for your eyes to adapt to the darkness. Look for and eliminate any sources of light from doors, ventilation sources, exhausts, and indicator lights on the processor or timer. (Black electrical tape works well for small leaks.) Turn the safelights back on.
- 3. Expose a cephalometric film in a cassette to x-rays to an optical density of approximately 1.00 (i.e., medium gray density when developed). Cephalometric film must be pre-exposed since it takes, on average, three photon hits to make a silver grain developable. This is due the fact that the film-based cephalometric systems use a screen-film setup instead of direct film exposure (no screen) for the film-based intraoral systems. In this case, a light fog exposure might not be apparent on a pre-exposed film, but this additional exposure to an exposed film would show fog. In contrast, for intraoral film, a one photon hit makes many grains developable. Hence, the exposure for the fog test will not make a difference.
- 4. In the darkroom, remove the film from the cassette, place it on the work counter, and cover one half of it with thin, opaque material.
- 5. Stand back from the counter so as not to cast a shadow on the film.

- 6. Leave the film on the work counter for two minutes and then process it.
- 7. After placing the film on a viewbox, use a pen to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive darkroom fog that comes from a light leak must be eliminated.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 8. If a density difference is visible, it may be due to
  - a. the wattage of the safelight bulb may be too high,
  - b. the safelight may be too close to the counter,
  - c. the safelight filter may be faded, damaged, or incorrect,
  - d. there may be too many safelights in the darkroom, or
  - e. there may be leakage of outside light into the room.

If one suspects the fog is due to the safelights (items a to d), one should repeat the test with the safelights turned off to confirm this.

**Daylight loader fog tests** are to be performed initially for a new daylight loading processor and at least annually thereafter. Fog tests should also be performed each time any lighting in the room is changed, e.g., light bulbs are replaced. In addition, a fog test should be performed any time changes are made to the daylight loader.

- 1. Expose a cephalometric film in a cassette to x-rays to an optical density of approximately 1.00 (i.e., medium gray density when developed). Cephalometric film must be pre-exposed since it takes, on average, three photon hits to make a silver grain developable. This is due the fact that the film-based cephalometric systems use a screen-film setup instead of direct film exposure (no screen) for the film-based intraoral systems. In this case, a light fog exposure might not be apparent on a pre-exposed film, but this additional exposure to an exposed film would show fog. In contrast, for intraoral film, a one photon hit makes many grains developable. Hence, the exposure for the fog test will not make a difference.
- 2. Place the film cassette in the daylight loader, remove the film from the cassette and cover one half of it with thin, opaque material.
- 3. Stand back from the counter so as not to cast a shadow on the daylight loader.
- 4. Leave the film for two minutes and then process the film.
- 5. After placing the film on a viewbox, use a pen or pencil to cover the dividing edge between the portions of the film that had been covered and uncovered. Determine if there is any visual difference in density between the two sides. If there is a difference, excessive light is entering the daylight loader.

**Note:** The human eye can detect density differences on the order of 0.01 where there is an edge discontinuity. This density difference is not significant. By placing an object (e.g., a pen) to cover the edge, the eye can detect a density difference on the order of 0.10 in optical density, which is a reasonable level to identify fogged film.

- 6. If a density difference is visible, it may be due to
  - a. a change in the daylight loader filter,
  - b. room lights may be too bright,

- c. the daylight loader filter may be cracked, faded, damaged, or incorrect, or
- d. the material in the ports of the daylight loader (where one places hands to access the inside of the daylight loader) may be worn, cracked, or some pieces may be missing.

#### 5.9 Quality Control for Digital Cephalometric Image Receptors

In digital radiography, quality control is essential to ensure proper image quality. Because of the extended dynamic range of digital detector response and subsequent image processing, underexposures may result in the loss of ability to perceive small density differences due to excessive quantum noise. Conversely, higher-than-optimum exposures will result in increased radiation dose to patients and staff.

Quality control for digital cephalometric radiography ensures optimal image quality and system functionality. QC should be carried out at regular intervals and whenever sensors are suspected to be damaged or are replaced. A monthly to quarterly interval may be appropriate for the uniformity and artifact evaluation. The test should be performed by the personnel on site and the results reviewed by the QMP during the evaluation of the site's QC program.

Currently there is no standard method for evaluating the image quality of cephalometric x-ray units. Consequently, one should follow the manufacturer's recommendations if available.

Prior to carrying out the uniformity and artifact evaluations, one should verify that the display used to evaluate the phantom image(s) is functioning properly. (One may also want to confirm that all the other display(s) on-site used to evaluate the clinical images are functioning properly.) This may be done by using test patterns such as the Society for Motion Picture and Television Engineers (SMPTE) Medical Diagnostic Imaging Test Pattern<sup>23,24</sup> (Figure 1a), TG18-QC pattern<sup>25</sup> (Figure 1b), or equivalent.

For the SMPTE pattern, the window width should be set to encompass the entire range of pixel values in the test pattern. The window level is set at the middle of the window width or the lowest value of the window width, depending on the system being used.

For the DICOM and the 16-bit TIFF format TG18-QC patterns, the window width should be set to encompass the range from 0 to 4095.<sup>\*</sup> The window level is set at either the center or the lower end of the window width, depending on the system being tested.

For either test pattern, the overall image should be inspected to ensure the absence of gross artifacts such as blurring or bleeding of bright display areas into dark areas. All the gray levels should be visible, and both the 5% and the 95% areas should be seen as distinct from the adjacent 0% and 100% areas. Brightness and contrast should be adjusted until these conditions are met. A detailed discussion of the TG18-QC pattern can be found in Section 4 of the AAPM Online Report No. 3.<sup>25</sup>

#### 5.10 Evaluation of Site's Quality Control Program

The QMP should evaluate the site's QC procedures and results annually. This should include a review of the QC activities performed by personnel on site, as well as the service history of the equipment.

#### 5.11 Scattered Radiation Survey

During the acceptance testing of the intraoral units, one may also want to perform a scattered radiation survey. This can be done by exposing a head phantom or a one-gallon milk jug filled with water using the typical clinical protocol and measuring the resulting scattered radiation at location(s) where

<sup>\*</sup> Care should be taken to ensure the test pattern used matches the specification of the system being evaluated. For example, if an 8-bit system is being evaluated, the 8-bit test pattern should be used to evaluate the system. Appendix III in Reference 25 provides a detailed description of the TG18-QC pattern in order to generate the required test pattern (such as the 8-bit version).

the site's personnel are likely to be located, e.g., near the control panel. Due to the low level of radiation expected, a meter with sensitivity sufficient to detect the small amount of radiation (in the 9 to 90 nGy or 1 to 10  $\mu$ R range) is recommended. It is advisable to use an instrument that is capable of operating in integrate mode and measure the scattered x-ray for the exposure. The use of the rate mode is impractical for exposures of short duration. An integrating energy-compensated solid state detector or integrating ion chamber is a good instrument choice.

Refer to Table 2 for a summary of acceptance and QC recommendations for intraoral, panoramic, and cephalometric dental units.

#### THE REPORT OF AAPM TASK GROUP 175: Acceptance Testing and Quality Control of Dental Imaging Equipment

#### Table 2: Acceptance and QC Recommendations for Intraoral, Panoramic, and Cephalometric Dental Units

Recommended Tests	Device(s)	Frequency	Tolerance
Tube head stability and positioning	Intraoral unit only	Annually	≤0.5 cm drift after I second
Leakage radiation and visual inspection	All (Intraoral, panoramic, and cephalometric) units	Annually	No leakage
Minimum SSD	Intraoral units only	Refer to Section 3.3	≥18 cm (above 50 kVp)
Circular collimation	Intraoral units only	Refer to Section 3.3	≤7 cm
Rectangular collimation	Intraoral units only	Refer to Section 3.3	≤2% of SID in each axis
X-ray beam slit length and width	Panoramic units only	Annually	Refer to Section 4.2
Cephalometric collimation	Cephalometric units only	Annually	≤2% of SID in each axis
Beam quality	All units	Annually	Refer to Table I
kVp accuracy	All units	Annually	Manufacturer specs, ≤10% without specs
Timer accuracy	Intraoral and cephalometric units	Annually	Manufacturer specs, ≤10% without specs
Exposure reproducibility	All units	Annually	Manufacturer specs, COV ≤0.05
Technique factors	All units	Annually	Published DRLs and Achievable Doses
mA or mAs linearity	Intraoral and cephalometric units	Annually if selection is available	Ratio ≤10%
Scattered radiation survey	All units	Acceptance testing	Refer to Section 3.14, 4.10, or 5.11
QC for digital receptor – uniformity and artifact	All units	Monthly to quarterly by site's personnel, reviewed by QMP annually	No significant non-uniformity or artifact is observed.
QC for digital receptor – phantom image	Intraoral units	Quarterly to semi-annually by site's personnel, reviewed by QMP annually	No deviation from baseline
Darkroom fog test	If darkroom is used	Annually	No visible difference
Film processing QC	If film processor is used.	Daily by site's personnel, reviewed by QMP annually	No deviation from baseline

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