Department of Health
PUBLIC HEALTH SERVICES - RADIATION PROTECTION UNIT

Tasmanian Government

Recommended Quality Assurance Programme for Dental x-ray apparatus

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Summary of Quality Assurance Requirements

This document provides recommendations to carry out the minimum quality assurance tests and performance criteria for x-ray equipment and other ancillary equipment used for dental radiography in Tasmania. This document covers quality assurance tests related the following apparatus:

- Intra-oral x-ray units mounted to the wall or ceiling of a dental surgery, or mounted on a mobile stand
- Hand-held intra-oral x-ray units
- Orthopantomogram (OPG) units
- Cephalometry units
- Cone Beam Computed Tomography (CBCT) units

These quality control tests are meant to be relatively simple and take a minimal amount of time to perform. More rigorous testing will still need to be carried out by accredited testers as required under Regulation 6 of the Radiation Protection Regulations 2016.

The nature of the testing required will depend on the type of imaging equipment and image receptor used. Different tests are required for imaging using film, phosphor plates or digital detectors such as CCD or CMOS sensors. If unsure about the type of x-ray system you have, consult the user manual or seek manufacturer advice.

Table 1- Recommended Quality Assurance tests for dental x-ray apparatus

Test	Frequency	Criteria
Tube head stability (intra-oral units)	**Daily**	**Tube head must remain stationary when placed into position for radiography.**
Mechanical and safety inspection (all units)	**Quarterly**	**All mechanical functions operating correctly and saftey features intact.**
Film darkroom	**As required**	**No excessive amounts of stray light**
Film processing	**As required**	**See Section 4 for details**
Image reject/repeat analysis (all units)	**Annually**	**Adult imaging: 6% - 10%** **Paediatric imaging: 3% - 7%**
Image quality audit (all units)	**Annually**	**No more than 10% of images of unacceptable quality**
Radiographic image quality (intra-oral, OPG, cephalometry)	**Daily/Monthly**	**See Section 7 for details**
Image display quality (digital imaging)	**Quarterly**	**See Section 8 for details**

1. Tube head stability (intra-oral and cephalometry units)

The tube head must remain stationary when placed in position for radiography [1]. This is vital for ensuring the best image quality possible and that images do not have to be repeated. This can be verified by a simple visual inspection at each imaging session or at a time set aside for daily quality control (QC) activities. If the tube head is found to be unstable during imaging, the manufacturer or a service engineer should be engaged immediately and the problem rectified.

2. Mechanical and safety inspection (all units)

Background

All dental x-ray imaging units must be subject to a full mechanical and safety inspection every three months. These checks could be performed by a clinical staff member such as Dentist, Dental Assistant or Dental Hygienist. The service engineer may also perform additional checks during periodic servicing of the equipment. All service reports should be kept along with the site QC records.

Procedure

Perform an inspection of the system to ensure safe and optimal operation, using the checklist below.

- Cables must be free of any breaks, kink or knots. Cables should not be situated underneath heavy equipment.
- Cables should not be placed in the path of trolleys and other portable equipment where they could be damaged.
- All control panel switches, indicator lights and displays (e.g. DAP display) must function properly and be clearly visible.
- The shielding around the x-ray tube housing must be intact with no defects that could lead to a significant leakage of radiation [2].
- Hand-held intra-oral units must have a backscatter shield fitted onto the end of the cone to protect the hands and body of the operator from radiation exposure [3].
- X-ray tube housing and generator must be clean with no oil leaks evident. X-ray tubes are oil filled for cooling and oil leak may indicate a problem with the x-ray tube.
- All image receptors (film, phosphor plates or digital) must be clean and kept within protective envelopes or cassettes when not in use [4]. If phosphor plates are used, it is recommended that an erasure process is undertaken monthly to remove any residual signal that may have built up on the phosphor plate.
- Light boxes used for viewing films shall be clean and provide an adequate light source for interpretation of radiographs. It is recommended that the light box includes a peripheral mask to block out any ambient light and also provides a means of magnifying the image [1, euro].
- All monitors used for viewing and reporting of dental images must be clean and free of scratches.
- X-ray tube, tube housing and generator models and serial numbers must be clearly marked and readable, either on the unit or in the user manual.
- Lead aprons must be free of any cracks or defects that could compromise shielding integrity.
- Where there is a barrier providing radiation protection for the operator, this must be in a good condition without any cracks or defects, and the operator's view of the patient during imaging must not be obscured.
- Radiation warning signs must be displayed on the door and all room warning lights must be functional.
- For units which allow the selection of different technique factors (kVp, mA, and/or exposure time), a chart which indicates which combination of technique factors to use in different clinical situations must be clearly displayed near the control panel. A suitable chart may be provided by the manufacturer of the unit.

After each inspection, the following must be recorded:

- Date of inspection
- Model and serial number of equipment
- Person performing inspection
- Inspection results

Corrective action

Issues directly impacting the safety of patient and/or staff must be resolved as soon as possible.

3. Film darkroom (x-ray film imaging)

Darkrooms used for developing x-ray film must not have excessive amounts of stray light. Excessive light can be a cause of 'film fog'. This is a uniform exposure of the film which degrades contrast and can lead to poor image quality. Films of poor image quality may need to be retaken, resulting in increased radiation exposure to the patient. Automatic 'daylight loaders' must also be checked for any defects that could allow undeveloped film to be exposed to ambient light [1, 4].

4. Film processing (x-ray film imaging)

It is important to follow the correct procedures and manufacturers recommendations when developing film manually or using automatic processors. A chart must be displayed which specifies:

- Correct operating temperatures of the developer and fixer solutions.
- For these temperatures, the corresponding length of time to leave the film in the solutions, and the corresponding rinse and wash times.

Film developer and fixer solution must be replaced at the correct intervals as specified by the manufacturer. The manufactures specified maintenance schedule for automatic processors must be followed [1, 4].

Chemicals used for film processing may be categorised as controlled waste by Environmental Protection Authority(EPA) Tasmania. Fore more information on controlled waste can be found from EPA : epa.tas.gov.au/regulation/waste-management/controlled-waste/controlled-waste-category-codes

5. Image reject/repeat rate analysis (all units)

Background

Rejected and repeated images represent unnecessary radiation exposure of patients. They also result in inefficiencies in the imaging process owing to wasted time and resources [4, 5]. Rejected and repeated images could be due to several causes, including but not limited to:

- Positioning
    - Incorrect alignment of x-ray beam with film or detector
    - Incorrect projection
    - Patient positioning errors
- Exposure error
    - Overexposure
    - Underexposure
- Film
    - Fogging (old film stock, inadequate storage conditions, darkroom light leakage etc.)
    - Developer temperature too high or low
    - Developing time too long or short
    - Developer solution too concentrated or dilute
- Artefact
    - Detector
    - Foreign object (jewellery, clothing, etc.)
    - X-ray tube
- Patient motion
- System error
- Study cancelled

An analysis of the rate of rejected/repeated radiographs should be undertaken annually by an experienced?? Dentist. The result of this analysis may be communicated to the relevant quality control or radiation safety committee. This may lead to a review of the patient set-up or imaging protocol.

Procedure

The simplest method for image reject/repeat rate analysis is to divide the total number of rejected and/or repeated images for the analysis period and divide by the total number of images acquired for the same period:

$$Repeat\ image\ rate\ (\%) = \frac{Total\ number\ of\ rejected\ and/or\ repeated\ images}{Total\ number\ of\ images\ acquired} \times 100\%$$

The reject/repeat images rate may be sampled in accordance with staff type (dentists or allied dental professional), examination type, equipment or room. This would allow more accurate identification of the reason for rejected or repeated images and remedial action to take. For example, the reject/repeat imaging rate for less experienced staff may be higher than for experienced staff. This may indicate areas for further

training. Information necessary for reject/repeat image analysis may be obtained directly from the imaging modality or from a Picture Archiving and Communications System (PACS).

Performance criteria

The optimal image reject/repeat rate will vary between practices, being dependent on factors such as staff experience and difficulty of the examination. A sample of at least 10% image should be selected and analysed to find rejection rate. Higher sample number will provide more accurate estimate of rejection rate.

Reject/repeat image rate should be below 8% for adult imaging ,and 5% paediatric imaging.

Investigation should be carried out if repeat rate is more than 10% for adult imaging and 7% for paediatric imaging.

Corrective action

The action to be taken will depend on the reasons for abnormally high or low repeat imaging rates. Abnormally high repeat imaging rates may indicate the need for retraining or equipment servicing. On the other hand, abnormally low repeat imaging rates can indicate poor compliance with the repeat analysis program or acceptance of poor quality images. In this case, a sample of images that have been accepted shall be reviewed to determine the level of image quality (see Image review).

If abnormally high or low repeat imaging rates are found, the reason(s) for this and the corrective action taken must be recorded.

6. Image quality audit (all units)

Background

Image quality must be reviewed annually to ensure imaging equipment and resources are being used optimally [4]. The dentist or dental hygienist should be vigilant in examining radiographs or CBCT scans as they are produced. Image quality audits may be carried out by an experienced dentist or experienced radiographer within the practice or organisation.

Procedure

The image quality audit may contain a sample of images that are representative of the types of images that are taken (e.g. bitewing or periapical radiographs, OPG, cephalogram or CBCT scan).

At least 30 images or 10% of each radiographic view should be assessed for image quality. A larger sample size would provide a more accurate picture of image quality within the clinic.

The images shall be scored as either 'excellent' (no faults), 'acceptable' (some fault not affecting interpretation of the image) or 'unacceptable' (major faults leading to the image being unsuitable for interpretation. If the image is unacceptable, the reason for scoring the image as such shall be recorded and used in further quality improvement measures. It is recommended that dental departments or practices adopt a set of quality standards for images or develops their own in-house standards [4].

The image quality audit may be conducted alongside the reject/repeat image rate analysis. For example, after the analysis of rejected and repeated images has been undertaken, an image quality audit of a sample of accepted images can be done.

Performance Criteria

The number of unacceptable images must not be more than 10% of those images audited.

Corrective action

If more than 10% of the images audited are of an unacceptable quality, the reason for the unacceptable quality must be ascertained and reasonable measures taken to rectify this (e.g. retraining or equipment service). All corrective actions taken must be recorded.

7. Radiographic image quality (intra-oral, OPG, cephalometry)

Background

A simple way to monitor the quality of x-ray exposure or film processing is to process a radiograph of a simple step wedge. This is a device with incremental thicknesses of an x-ray attenuator (e.g. aluminium) which will produce a range of film densities when radiographed [1, 4]. An example is shown in figure 1. The step wedge can also be used to monitor changes in the performance of phosphor plates or digital sensors.

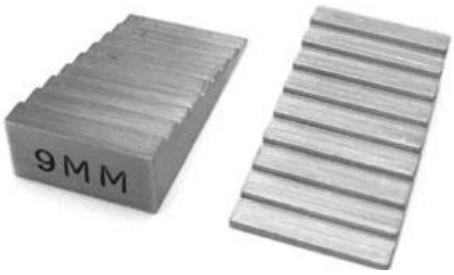

Figure 1: A step wedge for dental image quality control. Copyright Margraf Dental.

Procedure

- A reference radiograph must be produced using the standard method of image acquisition and processing. [1, 4]. An example of a reference radiograph is shown in figure 2.
    - If film is used the reference radiograph should be made when the developer and fixer solutions are changed or refreshed. The reference radiograph must be produced under optimal conditions (i.e. using fresh chemicals, unexpired film and correct exposure settings).
    - If phosphor plates or digital sensors are used, the reference radiograph should be made whenever a new batch of plates or sensors is acquired.

- When a reference radiograph is produced, it should be compared to the previously produced reference radiograph to check for any gross errors in image density.

- Each day, as clinical images are produced, a selection may be compared to the most recent reference radiograph to monitor the quality of film density or image exposure.

Figure 2: A reference radiograph, showing incremental increases in density. Copyright Margraf Dental.

Performance criteria

- Each reference radiograph produced must accurately represent all density changes without any gross artefacts.

- Clinical radiographs compared to the reference radiograph should accurately represent all density changes without any gross artefacts.

Corrective action

Density errors in the reference radiograph or clinical images may be due to a number of causes:

- Exposure errors (i.e. overexposure, underexposure)
- Errors in film processing (e.g. developer temperature set too high/low)
- Faulty film processing solution
- Faulty phosphor plate or imaging sensor

Exposure errors may be due to incorrect exposure settings, or a faulty x-ray tube. An equipment fault should only be considered once all other possible sources of error are eliminated.

8. Image display quality (digital imaging)

Background

For imaging with phosphor plates and digital image receptors, such as CCD and CMOS sensors, the monitor on which the image is displayed must undergo a standard QC procedure every three months. The test is done by visually inspecting the TG270-s QC Test Pattern on the reporting monitor. This test may be affected by user bias and so it should be performed by the same person every time, ideally the person who would normally read clinical images from the monitor.

The test pattern contains:

- 18 incremental grayscale patches at the top with low-contrast bar patterns - to assess luminance response[1] and uniformity.
- Three large grayscale patches (black, mid-grey and white) - to assess maximum and minimum luminance and luminance uniformity.
- A continuous grayscale gradient at the bottom - used to assess luminance calibration errors and other artefacts.
- High-contrast bar patterns in the bottom right corner - used for qualitative spatial resolution measurements [6].

Equipment

- TG270-s QC Quality Control Test Pattern, from the AAPM report No. 270 [6] (see figure 1). The display test pattern is free to download from AAPM webpage : aapm.onlinelibrary.wiley.com/doi/10.1002/mp.14227
- TG-18 QC Quality Control Test Pattern, from the AAPM report No. 18. This pattern should be available on commercial PACS systems and display monitors.

Procedure

- Ensure the ambient light conditions are like those used for reviewing or reporting images.
- The window width and window level should be set using the full dynamic range of the display (eg. window width 256, window level 128) [6].
- View the test pattern on the monitor used to view and report dental images.

Analysis and performance criteria

- Review the three rows of small grayscale patches. The low-contrast bar patterns must be visible in at least 12 of the grayscale patches.
- Zoom and pan the three large grayscale patches across the display. These should be uniformly visible at all areas of the display (i.e. no changes in brightness or contrast as they are moved across the display).

[1] Luminance refers to the intensity of visible light emitted from the surface of a display. Luminance response refers to the change in luminance per change in grayscale value [6].

- The grayscale gradient at the bottom should be displayed as a continuous change in grayscale values. There should be no obvious artefacts relating to incorrect display of grayscale values.
- The high-contrast bar patterns at the bottom right-hand corner should show alternating black and white bars one pixel wide in the horizontal and vertical directions.

Corrective action

If the required detail (low and high contrast bar patterns) are not visible in the image, or individual grey levels are not distinguishable, this may be due to several issues:

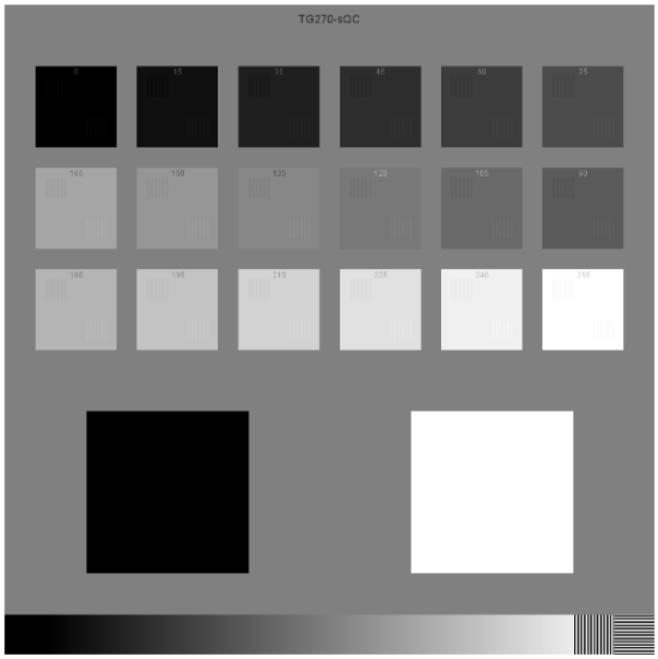

Figure 3: TG270-sQC test pattern for quality control of x-ray workstation displays and printed images. From reference 6.

- ambient lighting conditions are not ideal
- image window level and window width need adjusting
- monitor brightness and contrast need adjusting

If problems persist, contact the manufacturer of the monitor for remedial action.

References

[1] Australian Radiation Protection and Nuclear Safety Agency, *Radiation Protection in Dentistry*, Radiation Protection Series Publication No. 10 (2005)

[2] American Association of Physicists in Medicine *Acceptance Testing and Quality Control of Dental Imaging Equipment*, The Report of AAPM Task Group 175 (2016).

[3] AD Gulson and JR Holroyd, *Guidance on the Safe Use of Hand-held Dental X-ray Equipment*, Public Health England Report PHE-CRCE-023 (2016)

[4] European Commission, *European Guidelines on Radiation Protection in Dental Radiology: The Safe Use of Radiographs in Dental Practice*, Radiation Protection Issue No. 136, European Communities (2004)

[5] American Association of Physicists in Medicine, *Ongoing Quality Control in Digital Radiography*, The Report of AAPM Imaging Physics Committee Task Group 151 (2015)

[6] American Association of Physicists in Medicine, *Display Quality Assurance*, The Report of AAPM Task Group 270 (2019)