Quality Assurance in Dental Radiography

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BDS/BSC (HONS) RADIOGRAPHY

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Quality Assurance

' The purpose of Quality Assurance (QA) in dental radiology is to ensure consistently adequate diagnostic information, whilst radiation doses are controlled to be as low as reasonably practicable' (ALARP)

Guidance Notes for Dental Practitioners on the safe use of X-Ray Equipment

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Quality Assurance or Quality Control?

- Quality Assurance
  - "An organised effort by the staff operating a facility to ensure that the diagnostic images produced are of sufficiently high quality so that they consistently provide adequate diagnostic information at the lowest possible cost and the least possible radiation exposure to the patient" (WHO)
  - The arrangements to ensure that the quality control measures are effective and that they lead to relevant change and improvement
- Quality Control
  - The specific measures for ensuring and verifying the quality of the radiographs produced

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Quality Assurance

- Ensuring that standards are maintained at the highest level possible
  - Setting up a QA system
  - Maintaining the system
  - Clinical audit of radiographs

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Quality Audit

- The process of external reassurance and assessment that quality control and quality assurance mechanisms are satisfactory and that they work effectively
- At least annual review of whole QA programme
  - Responsible person

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A well designed QA programme

- Comprehensive
- Inexpensive to operate and maintain
- Well researched standards
  - Only infrequent modification
- "Written down common sense"
- Overall EFFICIENT SERVICE

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Setting up a QA System

ALL necessary procedures should be laid down in writing, including:-

- **(1) Implementation**
  - Responsibility of a named person
- **(2) Frequency**
  - How often operations are should be defined
- **(3) Records**
  - Content of the essential supporting records should be defined
  - Frequency for the formal checking of such records

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Aims of a QA Programme

- To produce diagnostic images of a consistently high standard
- To reduce the number of repeated radiographs
- To determines sources of error
- To reduce radiation dose to the patient
- To increase efficiency
- To reduce costs

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Maintaining a QA System

- This is achieved by a large number of items being implemented and maintained
  - Equipment Upkeep and Patient Dose
  - Examination Rooms
  - Image receptors and processing
  - Viewing and Reporting
  - Staff Training / Working procedures
  - Image Quality and Film Reject Analysis
  - Audit

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Staff and Equipment

- Employer is responsible for programme
- Nominated programme co-ordinator
- Staff should be trained and aware of own duties

- Range of specific parameters specific to each system
- Published guidance on recommended tests

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Test Equipment

- Generic equipment stated in published guidance
- Utilise features of system (DAP, KVp, mAs, dose)
- Phantoms may be supplied
- Equipment purchased by employer

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I/O Output Testing

- UNFORS Meter
- Set exposure
  - 60 kV, 7mA, 0.25 seconds
- Chair maximum height
- Place rectangular collimator on top of sensor
- Make exposure
- Record results
- Check within normal range

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- Every dental practice should have a QA programme
- Should include a Radiation Survey
  - At least once every 3 years on a routine basis

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- Exceed DRL
- Image quality fails to meet NRPB guidance
- Other significant performance weakness

Remedial action should be taken

Equipment tested more often until acceptable performance achieved

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Patient Dose

- Patient dose must be monitored at all times
  - ALARP
- **Diagnostic Reference Levels (DRL's)**
  - Patient dose should be measured regularly and compared to national DRL's (IOPA = 1.2mGy)
  - Image quality audit → Reduce exposure time → Re-audit
- Equipment needs to comply with regulations in order to achieve this

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- Equipment log and records
  - Installers written reports – checks, results and action
  - Results of all equipment checks in chronological order
  - Routine / Special maintenance details
- **Up-to-date Inventory**
  - Required by IR(ME)R 2018
    - Name of manufacturer
    - Model Number / Serial number
    - Year of manufacture / installation

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IPEM Report '91

- Institute of Physics and Engineering in Medicine (IPEM)
- Specific dental radiography chapter (9)
- Routine performance tests on x-ray equipment in practice or hospital

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Performance Tests

- Simple tests (Level A)
  - Dental Practice Staff
- Complex tests (Level B)
  - Trained personnel from equipment suppliers
  - Periodic testing by medical physicists
  - Other agencies which provide advisory services to dentists

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Dental Film Processing

Level A	Level B
• Developer temperature	• Film Processing (Gross fog, speed, contrast)
• Condition of processing solutions	
• Overall check of film processing (stepwedge)	
• Darkroom (or desktop day processor) light proofing	
• Integrity of safelights	

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Dental Radiography

Level A	Level B
• Condition of digital detectors	• Tube voltage
• Image quality	• Exposure time
• I/O image uniformity	• I/O beam size/collimation
• Panoramic uniformity and reproducibility	• I/O limiting spatial resolution
• Panoramic beam alignment and synchronisation of exposure with tube motion	• I/O dose at collimator tip for adult molar radiograph
	• Panoramic beam size/collimation
	• Panoramic DAP

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Patient Dose

- Patient dose must be monitored at all times
  - ALARP
- Dose Reference Levels (DRL's)
  - Patient dose should be measured regularly and compared to national DRL's (IOPA = 1.7MGy)
  - Image quality audit → Reduce exposure time → Re-audit
- Equipment needs to comply with regulations in order to achieve this

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Equipment Safety

- Critical Examination and Report
  - Carried out by the Installer (must consult RPA first)
  - Checking Safety Features
- Acceptance Test
  - RPA (before clinical use)
  - Includes measurement of patient dose
  - Verifies conditions of contract have been met
- Commissioning
  - Establish baseline and ensure ready for clinical use
  - RPA responsible
- Re-examination report
  - After relocation, repair or modification

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- Routine tests
  - Detects any significant changes in performance
  - Service carried out annually
- Equipment log and records
  - Installers written reports – checks, results and action
  - Results of all equipment checks in chronological order
  - Routine / Special maintenance details
- Up-to-date Inventory
  - Required by IR(ME)R 2018
    - Name of manufacturer
    - Model Number / Serial number
    - Year of manufacture / installation

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Daily Room Checks

- Exposure Warning Light Function
- Audible Alarm Function
- Counter Balance Arm Function
- Date and sign to confirm checked
- Six monthly periodic record to ensure checks done

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Dental Film Processing

Level A	Level B
• Developer temperature	• Film Processing (Gross fog, speed, contrast)
• Condition of processing solutions	
• Overall check of film processing (stepwedge)	
• Darkroom (or desktop day processor) light proofing	
• Integrity of safelights	

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Darkroom Regular Checks

- Cleanliness
  - Particularly work surfaces
- Light-tightness
- Safelights
  - Coin test
- Chemical Processing Solutions
  - Step wedge exposed and compared to test film
  - After every change of chemicals (according to Guidance for GDPs)
  - Solutions should always process an identical film or may be exhausted

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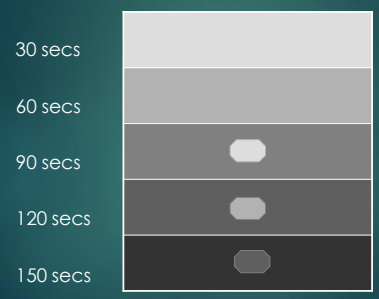
COIN TEST



FOR TESTING SAFELIGHTS IN OLD DARKROOMS

HOW LONG DID IT TAKE FOR THE COIN TO APPEAR? (IE. THE SAFELIGHT WAS THEN AFFECTING THE FILM). GET THE FILM INTO THE PROCESSOR BEFORE THIS STARTS TO HAPPEN

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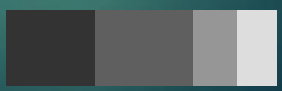
QUALITY ASSURANCE TEST TOOL FOR CONVENTIONAL IMAGING

STEP-WEDGE

Lead foil from x-ray film packet x 3,5,7,9 layers

Expose Step-wedge and assess image daily for changes in contrast / density



If contrast changing, new chemicals required

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- Manual Processing Equipment checks
  - Contaminated chemicals, light tight
  - Proper use of accurate timers, thermometers and immersion heaters
- Automatic Processing Equipment checks
  - Rollers cleaned
  - Chemicals replenished
- Record log of cleaning

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Films and Processing

- QA standards will be laid down by the suppliers of the films, processing solutions, and processing equipment and will include:
  - film speed, expiry date and recommended storage conditions
  - processing conditions (times and temperatures)
  - changing frequency for processing solutions
  - cleaning instructions for automatic processors

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Image Receptors

- **Radiographic Film**
  - Storage Conditions - Cool, dry, away from radiation
  - Stock Control - Avoids using expired film
  - Careful Handling
- **Film Cassettes**
  - Cleaning – Intensifying screens
  - Light-tightness
  - Film-screen contact – better definition if good contact

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Digital Image Receptors

- 2 different types
  - PSP (PhotoStimulable Phosphor Storage Plates)
  - CCD (Charge Coupled Devices)
- Cleaning
  - Recommended cleaner according to manufacturer (eg) Durr
- Checking
  - Scratches / frayed edges
  - Damaged receptors removed from circulation
- Handling
  - Gloves prevent damage
  - Double bag receptors?

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Consistency Test (I/O scanner)

- Carried out on Vistascan every month
- Tests scanner reading, not quality of PSP
- Method
  - Vistascan Test tool
    - Perspex block with copper insert
  - PSP placed inside tool
  - Exposure made
  - Test image produced and assessed

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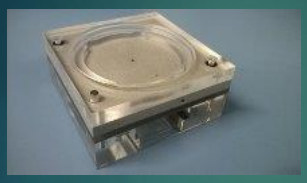
Vistascan Test Tool



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Assessing test image

- Line pairs should be defined
  - HIGH contrast
- Square and range of circles should be visible (can adjust contrast of screen)
  - LOW contrast

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Daily Room Checks

- Exposure Warning Light Function
- Audible Alarm Function
- Counter Balance Arm Function
- Date and sign to confirm checked

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QA Tests

- Constancy test
- Uniformity and Beam Alignment
- DENTest Phantom
  - Image Quality of whole system
- Monitor Calibration
- Exposure Release
- Emergency Stop

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Instructions and Record Sheets

- Written Protocol for each specific test (reproducible)
- Should include frequency
- Clear instruction of what to do with results
- Can generate graphs etc to identify trends
- Baseline/Action levels should be outlined
- Active sign off

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Constancy Test (OPT)

- Carried out every month
- Needle phantom used for exposure
  - Set exposure values
  - Phantom supplied with unit
- Test image produced
  - Compared to previous month
  - Both images should look the same (needle width, length etc)

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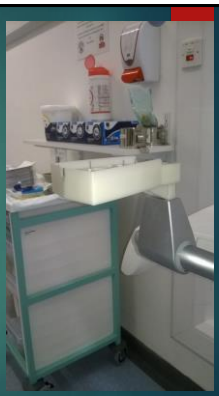

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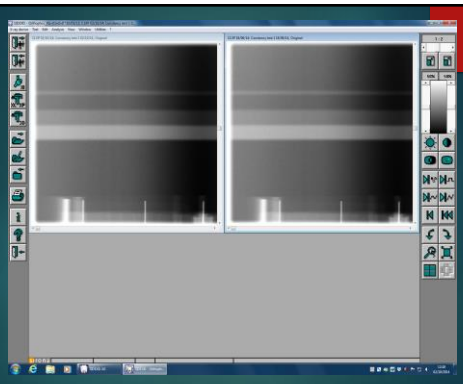

2D Constancy Check

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Uniformity and Beam Alignment (OPT/Ceph)

- Select QA patient on system
- Select same exposure each time (eg. paeds exposure)
- 1mm copper plate
- Take exposure and view image
- Check for artefacts and non-uniformities
- Check edge of radiation field visible on image
- Record PASS or FAIL

BASELINES SHOULD ALWAYS BE TAKEN INITIALLY AND USED TO COMPARE SUBSEQUENT TEST IMAGES TO

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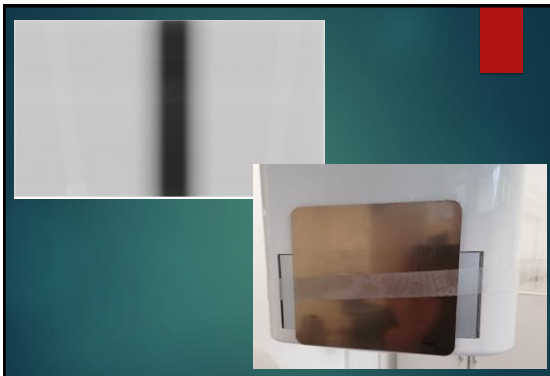

OPT UNIFORMITY IMAGE

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CEPH UNIFORMITY AND BEAM ALIGNMENT

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DENTAL X-RAY UNIFORMITY AND RADIATION ALIGNMENT TEST

DATE	UNIFORMITY		COMMENTS	TESTED BY	REPORTED TO
ROOM 3 OPT	PASS	FAIL			
ROOM 3 OPT	RADIATION ALIGNMENT				
	PASS	FAIL			

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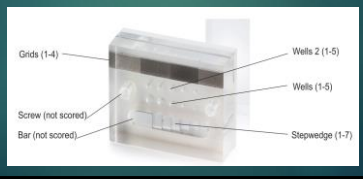
DENTest Phantom

- Select QA patient
- Select same exposure factors (lower anterior)
- Place phantom on Size 2 PSP
- Align rectangular collimator to phantom
- Make exposure and assess test image



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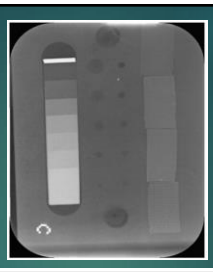

Group	Guide	
Step wedge	Count the number of distinct steps seen	All 7 steps and bar should show clearly
Grids	Count how many grids are clearly seen	Usually 3 of the 4 show well
Wells	Count the row of wells large to small	All 5 should show clearly
Wells 2	Count the row of small wells	All 5 should show clearly

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APPENDIX A

MONTHLY DENTEST QA PHANTOM RESULTS SHEET

DATE	STEP WEDGE	GRIDS	LARGE & SMALL WELLS	SMALL WELLS	PASS OR FAIL	TESTED BY	REPORTED TO
ROOM 1 and VISTASCAN COMBI PLUS RECEPTION							
ROOM 2 and VISTASCAN COMBI PLUS DARKROOM							

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Digital Radiography

- Similar QA procedures to film-based radiography
- Theoretically, image quality should be improved:
  - Chemical processing errors eliminated
  - Most exposure errors can be compensated for by using computer software particularly when using PSP
- Very easy to repeat radiographs
  - Properly justified?
  - Recorded ?
  - Included in QA statistics?

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Viewing Radiographic films

- Viewing Boxes
  - Fluorescent Tubes
  - Cleaning
- Screen Quality (monthly)
  - Better resolution means more accurate diagnosis
  - Medical grade screens
  - "Monitor Calibration Test"

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Medical Grade Screens

- Guidance available
  - Royal College of Radiologists (RCR)
- Minimum recommended screen resolution
  - 1.3 Megapixels (1280 x 1024)
- Resolutions up to 3 Megapixels (1500 x 2000)
- Screens at SOD = 1.9 Megapixels (1600 x 1200)

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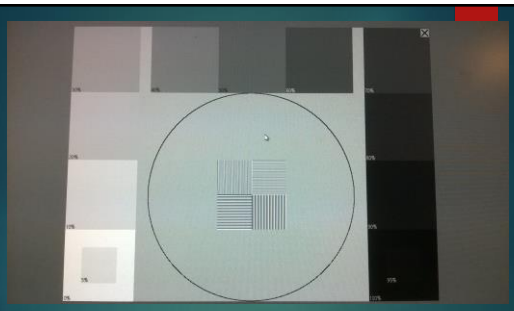

- Should be clear definition between 0 and 5% image (lower left)
- Should be clear definition between 95 and 100% image (lower right)
- Colour change between each box should be visually apparent
- Circumference of circle should be clearly defined (no large steps)
- Vertical and Horizontal lines should be clearly defined

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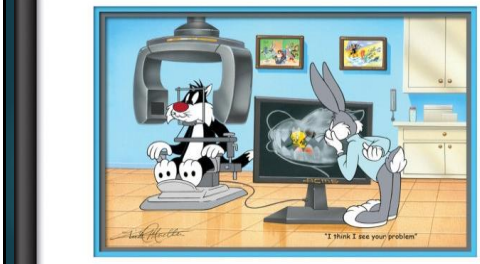

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Working Procedures

- **Local Rules**
- **Employers Procedures**
- **Systems of Work**
  - Written procedures for all actions that INDIRECTLY affect radiation safety and diagnostic quality
- **Procedures Log**
  - To record review of the above with regards to QA programme
  - Ideally <12 month review

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Staff Training

- Register of all Staff
  - Name, Responsibility, Date/details of training, recommended date for training review
- Training register should include:
  - Details of training provided for staff under IRR (NI) 2000
- All IR(ME)R practitioners and operators must:
  - Be adequately trained
  - Undertake CPD

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Clinical Audit

- Annual Review of full QA Programme (at least)
- Written records
  - Every procedure within the programme
  - Carried out by person responsible for programme
- Possible Clinical Audits
  - QA programme and associated records
  - Justification and Authorisation
  - Clinical Evaluation of radiographs

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Image Quality audit

- Carried out twice a year
- Recordings made for one month
- Information recorded in a table
  - Date
  - Patient number
  - Size of film used
  - Number of images
  - Quality standard 1, 2 or 3 (Now A and N)
  - Reasons for QS3 (Now N)

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QA Manual

- Folder containing all QA material
- Local QA policy
- Responsible staff list
- Protocols
- Result Sheets
- Baseline values
- Testing equipment list
- Reference material
- Contact names/numbers

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Image Quality Assessment of Radiographs

- National Radiation Protection Board (NRPB) guidelines for assessing the quality of radiographs
  - Grading System
    - Grade 1 – Very Good
    - Grade 2 – Good Enough for Diagnostic Purposes
    - Grade 3 – Unacceptable
    - **NOW CHANGED TO GRADE "A" AND "N"**

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Radiograph assessment

- Identification – not on dental x-rays
- Marker – pip raised when x-ray laid flat
- Area – correct area included?
- Projection – distortion? elongated? shortened?
- Contrast – black/white/grey
- Collimation – info collimated off image?
- Artefacts – dentures/necklaces/glasses etc
- Variation – anatomy normal?

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Grade 1 (QS1)

- Excellent Quality
- No errors of patient preparation, positioning, exposure, processing or film handling

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Quality Standards for Periapical Radiography (IOPA)

- Evidence of optimal image geometry
  - No overlap / elongation / shortening etc
- Correct anatomical coverage
  - Teeth in question from crown to root apex
- Adequate number of films
  - To cover area required
- Adequate processing and film handling techniques
  - No scratches / streaks etc

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EUROPEAN GUIDELINES - IOPA

Evidence of optimal image geometry
- There should be no evidence of bending of the teeth.
- There should be no foreshortening or elongation of the teeth.
- Ideally, there should be **no horizontal overlap**. If overlap is present, it must not obscure pulp/root canals.

B: Correct anatomical coverage
- The film should demonstrate all the tooth/teeth of interest (i.e. crown and roots).
- There should be at least 2-3 mm of periapical bone visible to enable an assessment of apical anatomy.

C: Good density and contrast
- There should be good density and adequate contrast between the enamel and the dentine.

D: Adequate number of films
- In endodontic treatment, it may be necessary to separate superimposed root canals using two radiographs at different horizontal angles..
- Assessment of some horizontally impacted mandibular third molars may require two films to image the apex.

E: Adequate processing techniques

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Quality Standards for Bitewing Radiography

- Evidence of optimal geometry
  - Contact points should be clear
  - No overlap
  - Cusps should be superimposed
- Correct anatomical coverage
  - From 1st premolar to 2nd molar (4-7)
- Good density and contrast
  - Caries can be diagnosed easily
- Adequate processing and film handling techniques
  - No scratches / streaks etc

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EUROPEAN GUIDELINES - BITEWINGS

- **A: Evidence of optimal image geometry**
  - There should be no evidence of bending of the image of the teeth.
  - There should be no foreshortening or elongation of the teeth.
  - Ideally, there should be **no horizontal overlap**. If overlap is present, it should not obscure more than one half the enamel thickness. This may be unavoidable due to anatomical factors (i.e. overcrowding, shape of dental arch)
- **B: Correct anatomical coverage**
  - The film should cover the distal surfaces of the canine teeth and the mesial surfaces of the most
  - posterior erupted teeth.
  - The periodontal bone level should be visible and equally imaged in the maxilla/mandible, confirming
  - ideal centring.

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- **C: Good density and contrast**
  - There should be good density and adequate contrast between the enamel and the dentine.
- **D: Adequate number of films**
  - When the third molars are erupted or partially erupted and impacted and all the other teeth are present, two films may be needed on each side to evaluate the dentition.
- **E: Adequate processing techniques**

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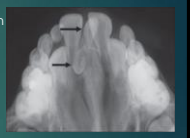
Quality Standards for Occlusal Radiography



- Evidence of optimal geometry
  - No elongation/foreshortening of anterior teeth
- Correct anatomical coverage
  - As far back as possible
- No rotation
  - Centred to patient's midline, head straight
- Good density and contrast
- Adequate processing and film handling techniques

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Quality Standards for Panoramic Radiography (OPT)

- Patient preparation / instruction adequate
  - No earrings / jewellery, tongue to roof of mouth
- No patient positioning errors
  - Mid-sagittal plane vertical, frankfort plane horizontal
- Correct anatomical coverage
- Good density and contrast
- No image receptor problems
- Adequate processing techniques

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EUROPEAN GUIDELINES - OPT

A: Patient preparation/ instruction adequate
Edge to edge incisors.
No removable metallic foreign bodies (e.g. earrings, glasses, dentures).
No motion artefacts.
Tongue against roof of mouth to ensure there is no air shadow obscuring the upper teeth.
Minimisation of spine shadow.

B: No patient positioning errors
No antero-posterior positioning errors (equal vertical and horizontal magnification).
No mid sagittal plane positioning errors (symmetrical magnification).
No occlusal plane positioning errors – Frankfort Plane (EAM ->LOM) parallel to the floor
Correct positioning of spinal column.

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C: Correct anatomical coverage
Appropriate coverage depending upon the clinical indication for the radiograph. Field size limitation techniques should have been used (if available) to exclude structures irrelevant to clinical needs (e.g. limitation of field to teeth and alveolar bone for everyday dental use).

D: Good density and contrast
There should be good density and adequate contrast between the enamel, the dentine and surrounding structures.

E: No cassette/ screen problems (with conventional radiography only)
No light leaks.
Good film/screen contact.
Clean screens.

F: Adequate processing techniques

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Quality Standards for Cephalometric Radiography

- Patient preparation / instruction adequate
  - No glasses, back teeth together etc
- No patient positioning errors
  - Not rotated, sides of mandible superimposed etc
- Correct anatomical coverage
  - Soft tissue border included, lower border of mandible, bridge of nose etc
- Good density and contrast
- No image receptor problems
- Adequate processing techniques

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EUROPEAN GUIDELINES - CEPHALOMETRIC VIEWS

A: Patient preparation/ instruction adequate
•Good explanation of procedure and of the need to stay still
•Teeth in centric occlusion (stable and natural intercuspation).
• Lips relaxed.

B: No patient positioning errors
• No antero-posterior positioning errors.
• No mid sagittal plane positioning errors.
• No occlusal plane positioning errors. Frankfort plane parallel to floor.
• Exact matching of external auditory meati with positioning devices.

C: Correct anatomical coverage
Visibility of all cephalometric tracing points required for the analysis.
Visibility of all anterior skeletal and soft tissue structures.

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D: Good density and contrast

E: No cassette/ screen problems (conventional radiography only)
No light leaks.
Good film/screen contact.
Clean screens.

F: Adequate processing techniques

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Grade 2 (QS2)

- Good Quality
- Some errors of patient preparation, positioning, exposure, processing and film handling
- Image is still of adequate diagnostic quality for the purpose intended and is therefore accepted

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Grade 3 (QS3)

- Poor Quality
- Many errors of patient preparation, positioning, exposure, processing and film handling
- These errors render the image diagnostically unacceptable, and the radiograph must be repeated to ensure adequate information for diagnosis

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New Minimum Targets for Radiographic Quality

95% Grade A

5% Grade N

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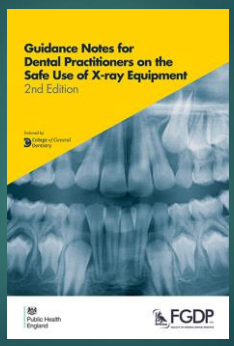
PROFESSIONAL GUIDANCE



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Quality Assessment

Are these dental radiographs grade 1, 2 or 3?

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Radiograph 1

Grade 2

Underexposed

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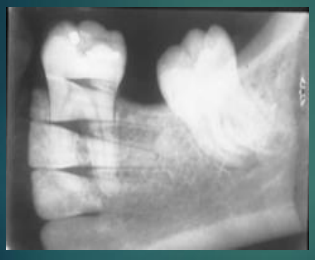
Radiograph 2



Grade 3

Double Exposure

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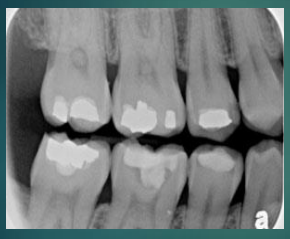
Radiograph 3



Grade 2

Posterior cone mark

Distal surfaces of canine not visible (ideal anatomy not covered)

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Radiograph 4

Grade 2

Foreshortened teeth

Incorrect angulation of tube

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Radiograph 5

Centre tooth – Grade 2

Adjacent teeth – Grade 3 for missed apices

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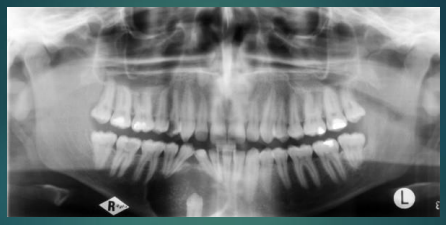
Radiograph 6



Grade 3

Lower border of mandible not included

Radiolucency not entirely visualised

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Reasons for Rejected Films

- Patient Factors
- Exposure Faults
- Positioning Errors
- Opacities
- Equipment Faults
- Digital Processing errors

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(1) Patient Factors

- Patient Movement
- Thin (dark) / Thick (pale) patient tissues
- Patient biting **too hard** on film packet
- Gag reflex

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PATIENT MOVEMENT

Vertical movement during exposure

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(2) Exposure Faults

- Underexposed
  - Wrong exposure time set by operator
  - Exposure switch not depressed for whole exposure
  - Faulty equipment (eg) timer
- Overexposed
  - Wrong exposure time selected by operator
  - Faulty equipment (eg) timer
- Double Exposure

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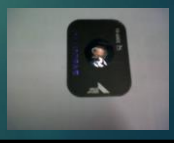
(3) Positioning Errors

- IOPA
  - Improper VERTICAL angulation of tubehead
    - Elongation / Foreshortening of roots
  - Improper HORIZONTAL angulation of tubehead
    - Contact points overlapped
  - Distortion of teeth due to film bending in corner of arch
  - Black lines caused by bent film
  - Areas collimated off image
  - Film around WRONG way



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Elongation and Foreshortening

- Elongation
  - X-rays perpendicular to object (tooth), but ***not to film***
- Foreshortening
  - X-rays perpendicular to film, but ***not to object***
- Distortion
  - Object and film perpendicular
  - X-rays ***not perpendicular to either***

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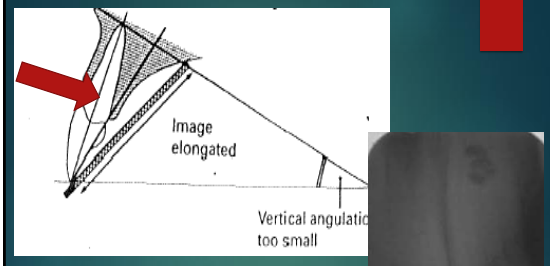
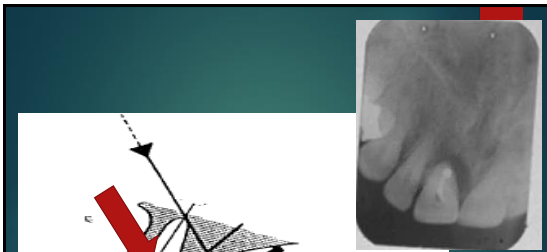


95



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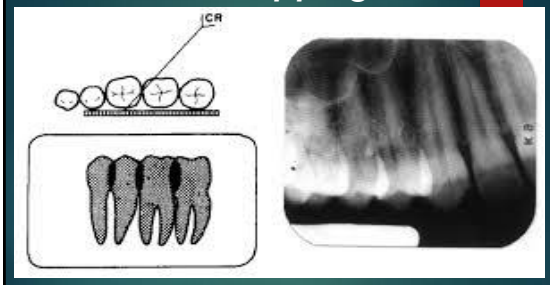
Overlapping



Not good for IOPAs! Cannot accurately diagnose caries☹

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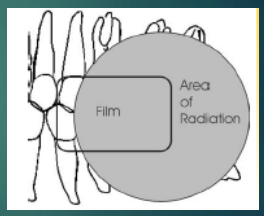
Coning off anatomy



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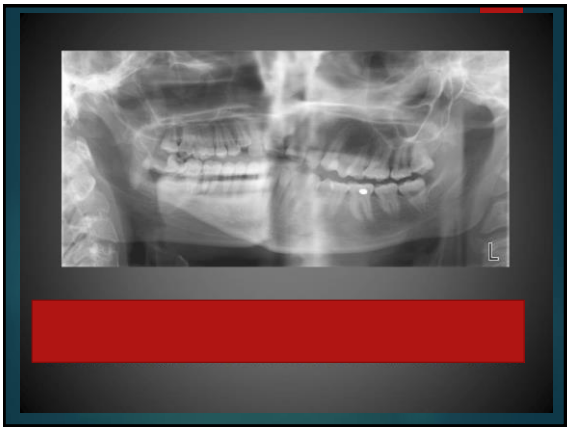

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Chin up

Chin down

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(4) Opacities

- Earrings
- Necklaces
- Piercings
- Dentures
- Orthodontic Appliances
- Glasses
- Inappropriate use of lead apron

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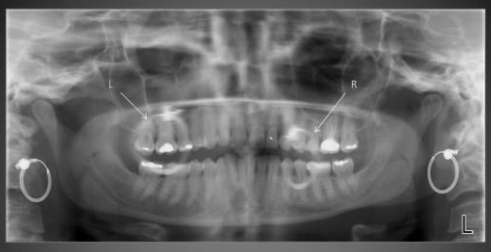

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Nightmare! Not one you would be proud of ☺
All that's missing is glasses!

103

Oh wait! There they are☺

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What on earth could this be?

Thyroid shield

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(5) Equipment Faults

- Faulty exposure timer
- Counter-balanced arm faulty

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(6) Digital Processing errors

- Peeling of PSP edges
- Fingerprints / Fingernails
- Bending of films
- Scanner errors

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(7) Darkroom / Processing errors

Dark images	Pale Images
Developer **temperature** too hot	Too cold
Developer **concentration** too strong	Too weak
Time in developer too long	Not long enough

- Developer exhausted / contaminated by fixer (pale)
- Insufficient chemicals to immerse films fully
- Emulsion tear (streaks / scratches)
- Fingerprints / Fingernails
- Overlapping of films during processing
- Bending of films

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- Stained films
  - **Dark stain – developer**
  - **Light stain – fixer**
  - **Dark spots in pattern – roller marks**
  - **Dark spots branched - static**
- Light Fogging
- Expired film used
- Faulty safelight – Dark (similar to fogging)
- Faulty cassettes allowing ingress of light – Dark
- Dirty intensifying screens in cassettes

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THANKS FOR LISTENING!

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