UPDATE ON ORAL AND MAXILLOFACIAL PEDIATRIC RADIOLOGY

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Radiation Protection & Radiation Doses

Intraoral Radiography Techniques

Extraoral Radiography Techniques

Non-Ionizing Radiation

Examples / Cases / Quiz – for you to explore -

ADA & AAPD recommendations
3 basic principles of radiation protection

- Justification
- Limitation (ALARA)
- Optimization

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# Electromagnetic Radiation

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>Wavelength</th>
<th>Photon Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio, TV, radar</td>
<td>3x10⁴ m to 100 µm</td>
<td>4.1x10⁻¹¹ eV to 1.2x10⁻² eV</td>
</tr>
<tr>
<td>Infra-red</td>
<td>100 µm to 700 nm</td>
<td>1.2x10⁻² eV to 1.8 eV</td>
</tr>
<tr>
<td>Visible light</td>
<td>700 to 400 nm</td>
<td>1.8 eV to 3.1 eV</td>
</tr>
<tr>
<td>Ultra-violet</td>
<td>400 to 10 nm</td>
<td>3.1 eV to 124 eV</td>
</tr>
<tr>
<td>X-rays and gamma rays</td>
<td>10 nm to 0.01 pm</td>
<td>124 eV to 124 MeV</td>
</tr>
</tbody>
</table>
Interactions of X-rays with matter:

- 100% absorption
- 100% penetration
- Partial absorption

**Dentistry:**

- Photo-Electric Effect (~ $Z^3$ and $1/E^3$)
- Compton Scatter effect (~ higher $E$)
Indirect Action

Radiation → $H_2O$ → $H^+$, $OH^-$
Ionization and excitation
$H^+; OH^+; HO_2; H_2O_2$
Free Radicals and Hydrogen Peroxide

Direct Action

Radiation → DNA → Molecular Damage

Mutation

Molecular Damage

Biological Response

Genetic → Somatic → Teratogenic

Death

$10^{-17}$ to $10^{-5}$ seconds

minutes to decades
Radiosensitivity and Cell Type:

Law of Bergonié & Tribondeau

= Radiosensitivity is greatest for cells with
  ➢ High mitotic rate
  ➢ Long mitotic future
  ➢ Undifferentiated

Head and Neck:

✓ Salivary glands
✓ Thyroid
✓ Lens of the eye
✓ Brain

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Radiation Sensitivity of Organ Systems:

<table>
<thead>
<tr>
<th>High Sensitivity</th>
<th>Intermediate Sensitivity</th>
<th>Low Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colon</td>
<td>Bladder</td>
<td>Bone Surface</td>
</tr>
<tr>
<td>Stomach</td>
<td>Liver</td>
<td>Brain- Nervous System</td>
</tr>
<tr>
<td>Lung</td>
<td>Thyroid</td>
<td>Salivary Glands</td>
</tr>
<tr>
<td>Bone Marrow</td>
<td></td>
<td>Skin</td>
</tr>
<tr>
<td>Female Breast</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Biological Effects of Ionizing Radiation

#### Deterministic Effects
- The effect is **proportionate** to the energy of the radiation
- There is a **threshold dose** under which there is no result
- Above that threshold dose one will see a specific effect
- Never in dentistry

#### Stochastic Effects
- There is a **chance** (probability) that there might be an effect
- There is **NO** threshold dose
- Therefore the effect can occur at any dose
- = dental diagnostic doses
Doses & Units?

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Radiation Absorbed Dose (D)

- Relates to the amount of energy per unit mass of tissue
- Gy = J/Kg
- 1 Gy = 100 RAD

Equivalent Dose (H)

- Relates to the type of radiation
- Sv
- 1 Sv = 100 REM
- $W_R$ X-rays = 1
- $H = W_R \times D$

Effective Dose (E)

- Relates to parts of the body
- Converting all doses to equivalent whole body dose
- Sv
- $E = H \times W_T$

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<table>
<thead>
<tr>
<th>Tissue</th>
<th>$W_T$ (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>Breast</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.12</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.05</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.05</td>
</tr>
<tr>
<td>Gonads</td>
<td>0.05</td>
</tr>
<tr>
<td>Liver</td>
<td>0.05</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.05</td>
</tr>
<tr>
<td>Bone surface</td>
<td>0.01</td>
</tr>
<tr>
<td>Brain</td>
<td>0.01</td>
</tr>
<tr>
<td>Kidneys</td>
<td>0.01</td>
</tr>
<tr>
<td>Salivary glands</td>
<td>0.01</td>
</tr>
<tr>
<td>Skin</td>
<td>0.01</td>
</tr>
<tr>
<td>Remainder tissues</td>
<td>0.10</td>
</tr>
<tr>
<td>X-ray investigations</td>
<td>Effective dose in µSv</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>CT chest</td>
<td>8000</td>
</tr>
<tr>
<td>CT skull</td>
<td>2000</td>
</tr>
<tr>
<td>Lateral skull radiograph</td>
<td>10</td>
</tr>
<tr>
<td>Frontal skull radiograph (AP)</td>
<td>30</td>
</tr>
<tr>
<td>Lateral radiograph chest</td>
<td>40</td>
</tr>
<tr>
<td>Frontal radiograph chest</td>
<td>20</td>
</tr>
<tr>
<td>Dental panoramic radiograph</td>
<td>7 to 30</td>
</tr>
<tr>
<td>Dental peri-apical radiograph</td>
<td>2 to 16</td>
</tr>
<tr>
<td>Dental CBCT</td>
<td>5 to &lt;1000*</td>
</tr>
<tr>
<td>Radiation Source</td>
<td>Average annual dose for an adult person</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td><strong>Natural background radiation</strong></td>
<td></td>
</tr>
<tr>
<td>Cosmic radiation</td>
<td>300 µSv</td>
</tr>
<tr>
<td>Earth’s crust radiation</td>
<td>400 µSV*</td>
</tr>
<tr>
<td>Nutrition</td>
<td>370 µSv</td>
</tr>
<tr>
<td>Radon and decay products</td>
<td>700 µSv</td>
</tr>
<tr>
<td>Europe</td>
<td>2000 – 2500 µSv</td>
</tr>
<tr>
<td>USA</td>
<td>3000 – 3500 µSv</td>
</tr>
<tr>
<td><strong>Artificial background radiation</strong></td>
<td></td>
</tr>
<tr>
<td>Fallout (~ Chernobyl, Fukushima, ...)</td>
<td>10 µSv*</td>
</tr>
<tr>
<td>Radioactive waste</td>
<td>2 µSv</td>
</tr>
<tr>
<td>Medical and dental diagnostic radiation</td>
<td>250 µSv*</td>
</tr>
<tr>
<td>Occupational exposure (e.g. aviation, nuclear plants, ...)</td>
<td>9 µSv</td>
</tr>
</tbody>
</table>

USA: 3000-3500 µSv/y
## Radiation Dose

<table>
<thead>
<tr>
<th>Radiation Dose</th>
<th>Main acute effects following large whole body doses of radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2500 µSv</td>
<td>Nil</td>
</tr>
<tr>
<td>2500 to 10 000 µSv</td>
<td>Changes in blood, lower WBC counts</td>
</tr>
<tr>
<td>10 000 to 20 000 µSv</td>
<td>Vomiting within 3 hours, fatigue, loss of appetite and blood changes (still reversible – recovery within a few weeks)</td>
</tr>
<tr>
<td>20 000 to 60 000 µSv</td>
<td>Vomiting within 2 hours, dramatic changes in the blood, hair loss within 2 weeks (recovery within 1 maand to a year in 70% of cases)</td>
</tr>
<tr>
<td>60 000 to 100 000 µSv</td>
<td>Vomiting within the hour, damage to intestines, severe and dramatic blood changes, death follows within 2 weeks in more than 80% of all cases</td>
</tr>
<tr>
<td>&gt; 100 000 µSv</td>
<td>Brain damage, coma, death</td>
</tr>
</tbody>
</table>

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Risk assessment...
<table>
<thead>
<tr>
<th>X-ray diagnostic investigation</th>
<th>Estimated risk of a fatal cancer (adult)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 dental radiographs:</td>
<td></td>
</tr>
<tr>
<td>50 kV, D-speed, circular collimation</td>
<td>1 in 2 million</td>
</tr>
<tr>
<td>70 kV, F-speed / digital, rectangular collimation</td>
<td>1 in 20 million</td>
</tr>
<tr>
<td>Dental panoramic radiograph</td>
<td>1 in 1 million</td>
</tr>
<tr>
<td>Skull frontal radiograph</td>
<td>1 in 670 000</td>
</tr>
<tr>
<td>Lateral skull radiograph</td>
<td>1 in 2 million</td>
</tr>
<tr>
<td>Frontal chest radiograph</td>
<td>1 in 1 million</td>
</tr>
<tr>
<td>CT chest</td>
<td>1 in 2500</td>
</tr>
<tr>
<td>CT skull</td>
<td>1 in 10 000</td>
</tr>
<tr>
<td>Dental CBCT</td>
<td>1 in 2 million -500 000?*</td>
</tr>
<tr>
<td>Age category</td>
<td>Multiplication factor for the risk estimation to develop a fatal cancer</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>&lt; 10 y</td>
<td>X 3</td>
</tr>
<tr>
<td>10-20 y</td>
<td>X 2</td>
</tr>
<tr>
<td>20-30 y</td>
<td>X 1.5</td>
</tr>
<tr>
<td>30-50 y</td>
<td>X 0.5</td>
</tr>
<tr>
<td>50-80 y</td>
<td>X 0.3</td>
</tr>
<tr>
<td>&gt; 80 y</td>
<td>X 0</td>
</tr>
</tbody>
</table>

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Take home messages:

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• **Doc, how high is this radiation?**
  Put it in perspective to annual background radiation dose when explaining.

• **Doc, I’m pregnant:**
  Non urgent diagnostic imaging can be postponed – urgent diagnostic imaging, protect the baby

• **Doc, it’s a child!**
  ALARA even more!

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Radiation Protection & Radiation Doses

Intraoral Radiography Techniques

Extraoral Radiography Techniques

Non-Ionizing Radiation

Examples / Cases / Quiz – for you to explore -

ADA & AAPD recommendations
Intraoral Techniques:

- **Bitewing radiograph**
  - Horizontal
  - Vertical
- **Periapical radiograph**
  - Parallel technique
  - Bisecting angle technique
- **Occlusal radiograph**
  - True upper occlusal
  - 45 degree lower occlusal
  - 90 degree lower occlusal
  - Oblique occlusals

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Periapical radiographs

- Image detector parallel to teeth
- X-ray beam perpendicular to image detector
  \[ = \textit{parallel technique} \]

- Image detector against teeth and soft tissue
- X-ray beam perpendicular to imaginary bisecting angle between long axis of tooth and long axis of image detector
  \[ = \textit{bisecting angle technique} \]

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Occlusal radiograph

• Larger field of view possible if one uses a phosphor storage plate size #4
• Difficult with solid state sensors
• Alternative to a periapical radiograph if nor parallel nor bisecting angle technique seem feasible
Use of the Protractor!!

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Upper standard Occlusal

- Position the patient **sitting straight up** in the chair – this allows the **occlusal plane to be parallel to the floor**

- Position the PSPP size 4 on the patient’s upper occlusal plane and ask patient to close mouth with the teeth touching the PSPP **gently**

- Position the X-ray machine with the spacer cone (BID/PID) **pointing down at 65°**, with the central X-ray through the bridge of the nose

- Verify if the projection of the spacer cone coincides with the circumference of the PSPP size 4

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Solid state sensor used with longest side transverse in the mouth = good alternative in the primary dentition.

Both images are taken at a 65 degree downward angle – size 4 on the left, size 2 on the right.

Long axis of PSPP size 2 plate anterior-posterior oriented
90 degree Occlusal of Mandible

- Position the patient **upright** in the dental chair and place a PSPP size 4 on the lower occlusal plane and ask to close mouth with teeth touching the plate gently. Then ask the patient to **tilt the head backwards** so the occlusal plane is perpendicular to the floor. Aim the X-ray machine **perpendicular at the PSPP** and check if the spacer cone’s projection coincides with the PSPP circumference.

**OR**

- Position the patient in **a supine position**, so the occlusal plane is perpendicular to the floor. Then place a PSPP size 4 on the lower occlusal plane and ask to close mouth with teeth touching the plate gently. Aim the X-ray machine **perpendicular at the PSPP** and check if the spacer cone’s projection is coinciding with the PSPP circumference.
Position the patient upright in the dental chair and place a PSPP size 4 on the lower occlusal plane and ask to close mouth with teeth touching the plate gently. The occlusal plane is now parallel to the floor.

Aim X-ray machine pointing upwards 45° through the tip of the chin. Check if the spacer cone’s projection is coinciding with the PSPP circumference.

This is also possible with a size 2 PSPP.
Occlusal plane perpendicular at the floor
Occlusal plane parallel to the floor
Illustrations of how to use a size 1 or size 2 PSPP for an occlusal radiograph taken in the mandible at a 45 degree angle

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Indications for Occlusal Radiographs

✓ Assess expansion of the bone in buccal and lingual dimension
✓ Assess the position of impacted teeth or foreign objects
✓ Assess sialoliths in the floor of the mouth
✓ 45° lower occlusal and 65° upper occlusal can be a good alternative to periapical radiographs (also possible with size 2 phosphor plates)
✓ Mandibular fractures and no 3D available
Oblique Occlusal in Maxilla

Position the **patient upright** in the dental chair so the occlusal plane is parallel to the floor.

Place a **size 2 or size 4** PSPP on the patient’s occlusal plane, make sure it can still be seen buccal from the tooth’s crown.

Ask patient to close teeth gently on the plate.

Position the **X-ray** machine at a **downward 65 - 45° angle**, with the central X-ray beam aiming through the apex of the tooth.
Oblique Occlusal in Mandible

Position the **patient upright** in the dental chair so the occlusal plane is parallel to the floor.
Place a **size 2 or size 4** PSPP on the patient’s occlusal plane, make sure it can still be seen buccal from the tooth’s crown.
Ask patient to close teeth gently on the plate.

*Ask patient to turn head to opposite side, so the body of the mandible is parallel to the chest and the shoulders do no longer interfere with the X-ray machine when in place.*

Position the X-ray machine at an **upward 25 - 30° angle**, with the central X-ray beam aiming through the apex of the tooth.

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Indications for Oblique Occlusal Radiographs

- Alternative to periapical radiographs (though less straightforward to carry out and therefore more prone to distortion)
- Gagging patients might benefit
- Young pediatric patients might benefit
- Special needs patients might benefit

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Take home messages:

• Easiest with analog film or PSPP
  **CAVEAT**: irreversible bite marks on the PSPP ($$$)

• Possible, but difficult with solid state sensors
  **CAVEAT**: biting on the cable ($$$)!

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2 wooden spatulas taped to the PSPP to protect the PSPP!
Radiation Protection & Radiation Doses

Intraoral Radiography Techniques

Extraoral Radiography Techniques

Non-Ionizing Radiation

Examples / Cases / Quiz – for you to explore -

ADA & AAPD recommendations
Extraoral Techniques

• **Panoramic radiograph**
  - Limited FoV
  - Bitewings

• **Cephalometric radiograph**
  - AP
  - PA

• **Oblique lateral radiograph**

• **Cone beam computed tomography**

• **Multislice computed tomography**

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Panoramic radiograph

- = tomography
- = challenging in a curved pathway, causing ghost images
- = focal trough (layer thickness) – most recent machines take image in “several layers” instead of a single layer
Modern panoramic machine:

- Temple supports
- C-arm
- X-ray source
- Chin rest
- Image receptor
- X-ray source
- Temple supports
- Handle bars
- Image receptor
- Bite block
- Handle bar
- johan.apsdmfr@hotmail.com
• The image receptor always passes at the front of the skull. Structures that need to be visualized should always be as close as possible to the image receptor.

• Because of the rotation, the structures on the sides are imaged twice: once in focus (when they are closest to the image receptor) and once out of focus (when they are closest to the X-ray source).
• Structures that are “out of focus” **always** cause so-called **ghost or phantom images**: these are projected over the real image of the other side.

• The spine is only exposed once to the X-ray beam. Therefore will not produce a ghost image!

• Some manufacturers **increase the kV** when passing the cervical spine, others will **decrease the rotation speed**. The latter helps to image the chin better, as one has to avoid a heavy shadow of the cervical spine in the middle of the image.
• The X-ray beam is **collimated** to a **vertical narrow slit**.

• The X-ray beam is aimed at an **8 to 12° upward angle**. This causes the image to be distorted slightly and magnified (approximately 1.3 times – depending on the manufacturer of the machine).

• **Hence, measurements on a panoramic radiograph are inaccurate!**
The focal trough

The focal trough has a **3D horse shoe shaped profile**.
The width in the **anterior region** is about **10 mm**, while in the **posterior region** it is about **30 mm**.
These measures can vary largely among different manufacturers.

Understanding the shape of the focal trough is important in order to be able to position the patient correctly in the machine and to be able to interpret the acquired image.

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Phantom / Ghost Image

- Both hard and soft tissues can cause these
- Can also come from jewelry, prosthodontics, foreign objects, surgical material, restorations, ...

- **Always projected higher in the image and on the opposite side**
- **Always blurred appearance**
- Can confuse the diagnostic yield!

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Phantom Image Principle

Out of focus

In focus

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Patient positioning = paramount

~ focal trough

- **Midsagittal plane** of the skull should be in the middle of the machine
- **Frankfort horizontal*** parallel to the floor
- **Lateral vertical line*** on canine or lateral incisor is used to find the correct **anterior-posterior position** of the patient in the machine.

*manufacturer

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If the patient is positioned correctly, the size of the mandibular rami will be symmetrical L and R.

Unless there is a real discrepancy in shape and size of the rami due to pathology or an anatomical aberration.
Caveat:

- The machine allows you to move the HORIZONTAL laser light over the patient’s face.
- HOWEVER this does NOT change anything to the machine.
- One has to move or change the PATIENT’S POSITION in order to make a difference! (= chin up or down)

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Mistakes in midline alignment cause the image to be distorted.

Structures closer to the X-ray source will be **magnified**.

Structures closer to the image receptor will be “**minified**”.
L ramus is closer to the X ray source, so magnification of the L ramus will occur.

R ramus is further away from the X-ray source, so will be projected normally/ slightly smaller than under ideal conditions.
Tilting of the midsagittal plane will result in an asymmetric image.

The condyles will be projected at different horizontal levels.

All distortions must be recognized in order to identify the positioning mistake.

If one decides to retake an image, one has to make sure not to make the same mistake.
If the **chin** is **too much down** (Frankfort horizontal is tilted down to the front) the condyles shift upwards in the image (sometimes beyond the border of the image) and the chin seems very large. This is also called the "**Joker Face**" image.
Chin down
Anterior nasal spine down
Condyles up
If the Frankfort horizontal is tilted down backwards, the condyles will be projected to the lateral sides of the image and sometimes will fall outside the image and the occlusal plane will be convex in the front and sloping to the back. This is often called the “sad clown’s face”.

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Condyles outward and down
Occlusal plane sideways down
Chin up
The neck should be straight when you position the patient in the machine. If the chin and the cervical spine are too close to each other (usually chin down tucked back) then a vertical radiopaque band will occur in the image, projected over the incisors and the chin.

Too many X-ray photons are absorbed by the dense mass that is formed by the mandible and the cervical spine.
This is the **IDEAL position** of the anterior teeth in the focal trough. Patient is asked to bite end-to-end in the bite block and if the crowns and the roots all fall within the focal trough, this will result in the ideal image without any distortion.

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Probably the **most REALISTIC situation** where the crowns of the teeth are in the focal trough, but the root tips are not. The inclination of the teeth will make the latter fall behind the focal trough, closer to the X-ray source, hence the magnification that will be noticeable on the image.

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Good positioning = better diagnostic yield
If one positions the patient **TOO FAR ANTERIOR** in the machine (the lateral vertical line did not coincide with the manufacturer’s guideline tooth and was more posterior), the teeth will be closer to the image receptor, thus will be “minified” in the image.
If the **patient is positioned TOO FAR POSTERIOR** in the machine (the lateral vertical line does not coincide with the manufacturer’s guideline tooth, it is anterior to that), the teeth will be “magnified” in the image, as they are closer to the X-ray source.
Now knowing and understanding how the principle of panoramic imaging works, one can modify the technique to image permanent teeth if desired in the primary dentition. Placing the patient, on purpose, more anterior, the tooth buds of the permanent incisors will be lying in the focal trough. The fact that the primary incisors will be hard to see as they will be “minified”, is no problem.

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Almost good …
Follow these steps:

1. Position the patient correctly in the machine (three lines!)
2. Make sure the patient’s head is immobilized (chin rest and temple rests)
3. Make sure the patient holds on to the handles
4. Check the patient’s shoulders (should always be below the rotating C-arm) – crossing arms might be useful in some patients
5. Check again if the patient is still biting in end-to-end position
6. Check once more the positioning lights and re-adjust the patient’s position if needed
7. **Tell your patient to:**
   - Keep lips closed
   - *Keep the tongue against the palate*
   - Refrain from swallowing
   - Refrain from moving / following the machine’s movement

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Take home messages:

• Patient Positioning!
• Patient Instructions!

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Panoramic Bitewings?

PM – Pro One®

PM – S2 Pan®

PM – S3 Promax®

Thank you Jim Hughes, Planmeca USA)
Limited FoV
Cephalometric radiograph

- **Lateral** radiographic view of the skull
- **Perpendicular** to the *midsagittal plane* of the skull
- Usually used for orthodontic and/or orthognatic surgery cases
- **Reproducible** because of the use of a *cephalostat*
- Dental counterpart of the lateral skull radiograph in general radiology

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Cephalostat

- 2 ear rods + 1 nose bridge rod/support
- Central X-ray through the external auditory meatus (one shot model = less patient motion artefact) OR patient ‘scanned’ from posterior to anterior (longer exposure time! = more chance of patient movement)
- Midsaggital plane should be perpendicular to the floor
- Teeth in maximal occlusion
- Neck straightened
- Standard orientation = image facing the right

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“One shot” technology (analog and some digital machines) = 1 second exp. (e.g. Kodak 8000®)

Posterior to anterior “scan” technology (digital machines with solid state sensors only) = several seconds exp. = movement artifacts? (e.g. Planmeca®)
Nose bridge rest with 10 mm markings

Soft tissues of the face must be visible

One ear rod will have a small metal ball and the other one a metal ring – the ball should be in the middle of the ring if the patient was positioned perfect in the cephalostat (can be used to test the alignment of the cephalostat)

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Indications

- Diagnosis of underlying skeletal pathology / aberrations
- Diagnosis of jaw fractures
- Diagnosis of underlying pathology or aberrations of soft tissues
- Planning for orthodontic treatment / orthognatic surgery
- Follow-up of any of the above
- Position assessment in the skull (combined with an anterior-posterior view of the skull) – these days often replaced by cone beam CT or MSCT (3D information!)
Anterior-Posterior Radiograph
Posterior-Anterior Radiograph
PA and head position?

- **Nose-forehead** against the image receptor = petrous part of temporal bone being projected “higher” in the image (maxillary sinuses better visible)
- **Chin-nose** against the image receptor = petrous part of temporal bone being projected “lower” in the image (orbits better visible)
“PA or AP ceph”

Caveat!

• L and R changes – check ear rods !!
• How should head be positioned? (chin up or down?)
• Midsagittal plane of skull should be perpendicular to the floor

• Even submento-vertex radiograph possible

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Take home message:

- Patient Positioning!
- Patient Instructions!
Oblique Lateral radiograph

Only possible with phosphor storage plate in a cassette. The phosphor storage plate should not be bent as the X-rays are supposed to be aimed perpendicular at the plate.

A regular intra-oral X-ray machine at 65 or 70 kV is used at exposure times as short as 0.16s. Sometimes 0.20s is necessary, if the patient has thick tissues. A circular collimator is standard for this exposure.

The aim is to obtain almost half the view of a panoramic image. Left and right side are imaged separately.
The patient is supposed to hold the cassette against the side of the face one intends to image. The X-ray machine is then positioned from the opposite side. The X-rays should go parallel to the occlusal plane, coming from behind the ramus of the mandible. (radiographic key hole = posterior of ramus and anterior of cervical spine)

This will provide one with an image of maxilla and mandible reaching from molars to canine.
Radiographic Techniques.
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Indications for Oblique Lateral Radiographs

- Alternative to intraoral and panoramic radiographs in specific patients (special needs, pediatric, elderly, ...)
- Patient with trismus
- Patient with severe gagging reflex
- Mandibular fractures if no 3D available
Take home messages:

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Requires PSPP plates or analog film in a cassette

Learning curve!

Very helpful in patients with special needs!
Cone Beam CT

- Cone beam shaped X-ray beam
- Intermittent beam (most of the machines)
- 180°, 270°, or 360° single rotation
- Field of View (FOV) (adjustable / not adjustable)
- Resolution (adjustable / not adjustable)
- kV and mA adjustable
- Cylinder or Sphere scanned (~ FOV)
- Majority has patient in upright position (sitting / standing)
Cone beam rotation arc

Three dimensional pixels = voxels
Field of View (FOV)

The larger the FOV, the higher the radiation dose for the patient.

**FOV should be as close to the ‘Region of Interest’ (ROI) as possible.**

Usually a small FOV is combined with a high ‘resolution’ (detail) and vice versa.
Resolution (75 µm – >600 µm)

Radiation dose is proportionate to the resolution.
200µm resolution image = 2 x dose from a 400 µm resolution image

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- Voxel size: **isotropic** voxels and not **anisotropic** voxels like (older) multi slice CT

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Multislice CT

- Fan shaped beam
- Multiple detectors
- Patient supine
- $$
MSCT – spiral motion of the fan shaped beam – continuous radiation – enables a stack of slices to be collected and provide a three dimensional image which includes soft tissue information.
<table>
<thead>
<tr>
<th>Tissue</th>
<th>HU (CT Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>-1000</td>
</tr>
<tr>
<td>Lung</td>
<td>-300</td>
</tr>
<tr>
<td>Fat</td>
<td>-20 to -100</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
</tr>
<tr>
<td>Heart</td>
<td>24</td>
</tr>
<tr>
<td>White Matter</td>
<td>24-36</td>
</tr>
<tr>
<td>Gray Matter</td>
<td>32-44</td>
</tr>
<tr>
<td>Muscle</td>
<td>44-59</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>60-110</td>
</tr>
<tr>
<td>Dense Bone</td>
<td>1000 or more</td>
</tr>
<tr>
<td>Iodine Contrast</td>
<td>1000 or more</td>
</tr>
</tbody>
</table>
Beam Hardening Artifact

Streaking artifacts like in CBCT
Take home messages:

- Soft and hard tissues investigations (HU)
- TMJ disk can be studied 😊
- Pathology invading bone and soft tissues (HU)
- Also beam hardening artifacts 😞
- Resolution might not be sufficient for dental issues 😞
- $$$!


- 9 different CBCT machines
- Small, medium and large FOV
- Dosimetry with TLDs and Rando phantom
- Image quality assessment

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What happens when we change the kV?

90 kV vs. 60 kV

What happens when we change the mA?

90 kV 5 mA  90 kV 1 mA

What happens when we change the rotation arc?

Full rotation vs. Half rotation


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Artifacts on CBCT

- **Metal** artifacts (crowns, amalgam, posts, foreign objects, …)
- **Gutta percha** (not all types give the same artifacts and not all sealers give the same artifacts)
- **Movement** or motion artifacts (incl. heavy breathing / heavy heart beat)

Axial views !!!
Motion artifacts

Ti or Pb?
Thyroid shielding?

50% reduction in thyroid dose

Qu X, et al. Dose reduction of cone beam CT scanning for oral and maxillofacial regions with thyroid collars. ICDMFR 2011, Hiroshima, Japan.

But be careful; should not interfere with the FOV !!!!
Problems with CBCT

✓ Patient movement
✓ Artefacts from radiopaque materials
✓ Resolution has to be matched with pathology or issue
✓ Cannot be used to visualize the articular disks or any other soft tissues accurately

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Positioning of the patient!
Instructions to patient!
Movement = disaster!
FOV = ROI
ALARA
Interpretation can be challenging
Non-Ionizing Radiation

- Magnetic Resonance Imaging
- Ultrasonography
- Transillumination
- Fluorescence
- Thermography
- ? Future ?

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Magnetic Resonance Imaging

• Hydrogen nucleus is a single proton
• Has a spin
• Has a charge
• Creates a magnetic moment vector $\mu$
• Quantum mechanical (but analogous to a spinning top or a compass needle)
Hydrogen spins are oriented randomly in zero magnetic field. In an applied magnetic field, the spins tend to align with the applied field (like a compass needle). The “net magnetization” is what we manipulate to generate signals in MRI.
MRI Precession

- The protons experience a torque perpendicular to the applied magnetic field which causes the magnetization vector to precess (like a top).

- The frequency of this precession (known as the Larmor frequency) is proportional to the applied field.
MRI

- Resonance: protons can absorb electromagnetic waves (radio waves) at the precession frequency
- Precessing spins cause a time-varying voltage signal in a coil or antenna
- The signal is also at the precession frequency
- The time to relax back to the tissue’s equilibrium state is measured and the differences in relaxation time for different tissues is used to form the MR image
MRI  Relaxation Time

- Over time the protons will relax and move back into equilibrium
- The signal diminishes over time
- The relaxation time is used for image contrast

---

**FIGURE 12-15** Top. Conversion of longitudinal magnetization, $M_z$, into transverse magnetization, $M_y$, results in an initial phase coherence of the individual spins of the sample. The magnetic moment vector precesses at the Larmor frequency (stationary in the rotating frame), and dephases with time. Bottom. In the laboratory frame, $M_x$ precesses and induces a signal in an antenna receiver sensitive to transverse magnetization. A FID signal is produced with positive and negative variations oscillating at the Larmor frequency, and decaying with time due to the loss of phase coherence.
T1 and T2 weighted MRI

**Fat**
- Fat regains longitudinal magnetization rapidly.

**Water**
- Water regains longitudinal magnetization slowly.

**FIGURE 12-24** T1-weighted contrast: Longitudinal recovery (left) and transverse decay (right) diagrams (note the values of the x-axis time scales) show four brain tissues and T1 and T2 relaxation constants. T1-weighted contrast requires the selection of a TR that emphasizes the differences in the T1 characteristics of the tissues (e.g., TR = ~500 ms), and reduces the T2 characteristics by using a short TE so that transverse decay is reduced (e.g., TE ≤ 15 ms).

T1 : fat shows stronger signal
T2 : water shows stronger signal
Magnetic Field Strength

- The units of magnetic fields are Gauss and Tesla
- 1 Tesla = 10,000 Gauss
- The earth’s magnetic field = ± 0.5 Gauss
- A refrigerator magnet = ± 100 Gauss
- MRI units = 1.5 T or 3.0 T (15k or 30k Gauss)

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MRI Safety

- Patients and personnel must not enter the scan room with any ferromagnetic material on their body. This includes watches, keys, credit cards, instruments, tools etc.
- In event of an emergency a specially equipped crash cart containing non-ferrous objects is used to render support to a patient
- Even the patient gurney or bed must be made of non-ferrous materials
- Under no circumstances should an oxygen bottle be brought into the MRI scanner room
- Special precautions must be given to patients who have an implanted pacemaker or ferromagnetic material.

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Thank you Prof. P. Heintz, Albuquerque, VA
CAVEAT: RF Fields – Local Heating

RF fields can also cause burns by inducing currents in:

– metallic objects: earrings, tattoo ink

– electrical equipment in contact with the patient: the MRI coil itself, cables associated with monitoring

– the patient: toes touching, knees touching, hands against body (avoid closed loops formed by extremities)

http://www.simplyphysics.com/burns/

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• Non ionizing radiation
• Small risks (possible burns)
• Artifacts from gold crowns, posts, ...
• Noise 😞
• Claustrophobia 😞
• Soft tissue study 😊
• TMJ (even video)

https://www.youtube.com/watch?v=ZnNgMnSfAws
Ultrasonography

- Known from ObGyn >>
- Known from physiotherapy
- Safe!
- Live images 😊
SOUND

• Sound travelling through air can be “heard” if the compressed air hits the tympanic membrane of the ear and makes it vibrate.

• High frequency of the vibrations = high pitch of the sound.

• **Humans** can hear frequencies **between 20 Hz and 20 kHz** (= wavelengths of 17m to 17 mm).

• > **20 kHz** = inaudible by humans, but audible by bats, dogs and dolphins = **ultrasound**.
infrasound

20Hz

20kHz

40Hz & > 20kHz

acoustic

ultrasound

1939, Sokolov: ultrasonography

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Medical ultrasonography

• **Piezoelectric effect:**

A potential difference applied to a crystal will cause distortion of the crystal. Removing the potential difference results in the crystal to return to its original shape. By doing so it **oscillates within ultrasonic frequency ranges.** These ultrasound waves are directed into the patient’s tissues.

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Ultrasonography

- **Transducer**: the device that produces and detects ultrasound waves
- **Every millisecond** a pulse of ultrasound is produced. The pulse lasts for 1 microsecond. The remaining 999 microseconds are used to detect the pulse (= echo) returning from the tissues.
Ultrasonography

- Air is not a good medium for ultrasound, so a coupling agent (gel) between transducer and tissues is needed to get rid of the air.
- Since different tissues have different acoustic impedances (depends on the density of the tissue and the velocity of the ultrasound), different echoes will be detected from the different tissues, enabling one to distinguish between different types of tissue.

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Pulse transmission control unit

Echo receiving and time unit

gel

transducer

UNIVERSITY of WASHINGTON

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Diagnostic Ultrasound

Diagnostic purposes = 2.5 – 40 MHz ( = 10^6 Hz)

- Low frequency to view deeper structures
- High frequency to view more superficial structures

Each tissue reflects the ultrasound differently. As the waves are reflected, they travel back through the more superficial layers, which render the echos weaker. Hence an amplification is necessary (time gain compensation TGC).

The opposite is necessary for the superficial reflected ultrasound waves.

The reflected ultrasound waves are transformed into an electrical signal, which is used to compose a digital black/grey/white live image.
Terminology

“Echoic”
• Hyper-echoic (bright)
• Hypo-echoic (dark/grey)

“An-echoic”
(black)
Applications (1/2)

- Ultrasound guided fine needle aspirations
- Ultrasound guided botox injections (salivary glands of patients why sialorrhea)
- Adjunct to sialography in diagnosis of Sjogren’s syndrome, sialadenitis, sialolithiasis, tumor of the salivary gland, etc.
- Imaging of the masticatory musculature
- Imaging of lymph nodes

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Applications (2/2)

- Ultrasound Color Doppler effect to investigate perfusion of the tissues
- TMJ disc imaging (+/-)?
- Masses in the tongue
- Intermaxillary suture expansion follow-up
- Healing process evaluation (e.g. muscular-skin flaps to repair intraoral defects after tumor resection)
- Detection of foreign objects/tooth fragments in the soft tissues

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Transducers

Different shapes are possible, depending on the application:

- Convex array
- Flat linear array
- Mini convex array (body cavity exploration: vagina, rectum, oral)
- Transesophageal echo probe
ULTRASOUND

ADVANTAGES

1. Non-invasive
2. Inexpensive
3. Quick
4. Comfortable for patient
5. Ideal for soft tissue diagnostics
6. No ionizing radiation

DISADVANTAGES

1. Rather poor resolution
2. Air and bone cannot transmit the US waves and anything beyond is “out of reach”
3. Operator dependent
4. Interpretation is difficult
Bialek et al., 2006:  
Salivary gland diagnostics with ultrasound imaging. Very useful and certainly first line of fire in diagnosing salivary gland problems.

Ngu et al. & other publications and congress presentations:  
Ultrasonography as first aid in salivary gland diagnostics. High value in Sjögren’s syndrome diagnosis and lymphnode identification.

Li et al., 2012:  
TMJ diagnostics with ultrasound is very limited, but can in certain cases be a good first line of fire tool in assessing the soft tissue TMJ problem.

Katzberg, 2012:  
TMJ diagnostics with ultrasound is not possible, as the ultrasound wave is straight and bone blocks the ultrasound waves. The thin gap between the condyle and the fossa glenoidalis is too narrow to allow good diagnostic images.
ULTRASONOGRAPHY: MAXILLOFACIAL APPLICATIONS

Gaurav Pratap Singh,1 Shikha Dogra, 2 Ekta Kumari 3

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2. Reader, Department of Pedodontics & Preventive Dentistry, College of Dental Sciences, Bhavnagar, Gujarat
3. Tutor, Uttaranchal Dental College & Medical Research Institute, Dehradun

Abstract

Ultrasonography (US) is one among the more commonly used imaging modalities for diagnosing maxillofacial diseases and disorders. It’s an inexpensive, easy to use and non-invasive technique when we compare it with other maxillofacial imaging modalities like computed tomography, Magnetic Resonance Imaging, Positron Emitting Tomography etc. Use of US in maxillofacial region imaging has been explored much in recent years and found to be important in diagnosing Solid and cystic swellings of head and neck region, space infections, intraosseous lesion of jaw etc. Development of high-resolution US and US-elastography has stretched its uses in diagnosis of TMJ disorders, carcinoma of tongue, cervical lymph node metastasis etc. Other than these US have also been of use for Guided Fine Needle aspiration. Though in present scenario US is being used to diagnose multiple numbers of maxillofacial diseases but it is yet to have its share in maxillofacial imaging as a routine diagnostic aid.

Key Words: - Guided-FNAB, Maxillofacial Applications, Maxillofacial imaging, Ultrasound, Ultrasonography.

RESEARCH ARTICLE

Ultrasonography in the evaluation of the mid-palatal suture in rapid palatal expansion

I Gunussoy, O Miloglu, I S Bayrakdar, S Dagistan and F Caglayan

Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Ataturk University, Erzurum, Turkey
• Soft tissue diagnostics 😊
• Operator dependent 😞
• Experience required
• Great potential in the future
• Safe!

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Practice...
Adenomatoid odontogenic tumor (AOT)
Thank you Dr. kreps (B)

Amelogenesis imperfecta

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Mach Band Effect: shadow of the tongue
Mucous retention cyst in R maxillary sinus
Monoradicular second and third maxillary and mandibular molars
Three rooted first mandibular molars

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SLOB
Same lingual – opposite buccal

Thank you Dr. Vanderborgh (B) johan.apsdmfr@hotmail.com
Double supernumerary posterior of upper central incisors … and a supernumerary tooth between lower left lateral incisor and canine
#16 positioned in furcation of #15

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Dentinal dysplasia

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Dens in dente of mandibular premolar
ejohan.apsdmfr@hotmail.com
Sialolith in the right submandibular salivary gland

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Multiple supernumerary (retained) teeth: Cleidocranial dysplasia
Papillon-Lefèvre Syndrome (hyperkeratosis palmoplantaris)
Course material of King’s College, University of London
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Thank you Dr. Kit Steen (Seattle)
Transposition #27 and the gubernacular canal

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Coin in the nasal cavity

Thank you Dr. Bernard Friedland (CA)
Calcifying odontogenic cyst

DDX: ameloblastic fibro-odontoma / dentigerous cyst with secondary infiltrations
#2 with extra cusp buccally … caries prevention!!
Cleidocranial Dysplasia (hyperdontia)
Cherubism
Thank you Dr. D. Dean, UW OM Dept.

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cementoblastoma

Dens bony island / osteosclerosis
Dens bony island / osteosclerosis
And generalized occlusal wear

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Dentigerous cyst #31
Dentigerous cyst #16 / keratocystic odontogenic tumor / ameloblastoma
Dentinal dysplasia

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Regional odontodysplasia / dentinal dysplasia

Thank you Dr. A. Eloot (B)
Dentinal dysplasia

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Dentinogenesis imperfecta
Ectodermal dysplasia

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Internal/external resorption #19 – one needs more slices to conclude

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Lesser wings of the sphenoid bone / floor of the anterior cranial fossa
Keratocystic odontogenic tumor / traumatic bone cyst / ameloblastoma
Molar-incisor hypomineralization (MIH)
Mystery case: idiopathic intracoronal resorption
(no history of bleaching either)
#31: not erupted (dentigerous cyst or just stuck?)
#32: superior of the crown = complex odontome / ameloblastic fibro-odontome

Thank you Dr. A. De Witte (B)
Periapical cyst / granuloma due to a dens in dente (dens invaginatus)
Impacted #27 and #26
Large complex odontome in symphyseal area

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Thank you Dr. E. Sarvas (USA)

Beads in #E and #F
90 degree mesiorotation #8, with talon cusp?
Traumatized #F with aberrant resorption (clinic: sinus tract buccal)
Thank you Dr. T. Takenaka (Washington)
Iatrogenic dentistry

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Acute lymphatic leukemia – underdeveloped tooth buds

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Hyperdontia
Ameloblastic fibro-odontoma

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Thank you Dr. M. Jeannin (B)
Dentinogenesis imperfecta

Thank you Dr. M. Jeannin (B)

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#17, position of the IAN canal = lingual
#32: roots perforating the lingual cortical plate of the mandible and IAN canal in apical furcation!

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Symphyseal fracture in a 4 year old boy
#32: lingual tilt, crown inferior and perforating the lingual cortical plate and apex impinging on buccal cortical plate – IAN canal runs partially in touch with the crown of the tooth (no cortication around the canal in this location...
Supernumerary tooth / compound odontome
Supernumerary tooth / compound odontome
Supernumerary tooth / mesiodens / compound odontome
9 year old boy with special needs, purulating extraoral fistula from periapical inflammation
Significant generalized occlusal wear
#18: uniform radiolucent, not corticated, periapical lesion

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Ectodermal dysplasia

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Radiation Protection & Radiation Doses

Intraoral Radiography Techniques

Extraoral Radiography Techniques

Non-Ionizing Radiation

Examples / Cases / Quiz – for you to explore -

ADA & AAPD recommendations
ADA & AAPD recommendations

- Clinical examination first
- Radiographs to be selected on a patient individual basis
- No routine taking of radiographs
- ALARA
<table>
<thead>
<tr>
<th>TYPE OF ENCOUNTER</th>
<th>PATIENT AGE AND DENTAL DEVELOPMENTAL STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child with Primary Dentition (prior to eruption of first permanent tooth)</td>
<td>Adolescent with Permanent Dentition (prior to eruption of third molars)</td>
</tr>
<tr>
<td>New Patient* being evaluated for oral diseases</td>
<td>Adult, Dentate or Partially Edentulous</td>
</tr>
<tr>
<td>Individualized radiographic exam consisting of selected periapical/occlusal views and/or posterior bitewings if proximal surfaces cannot be visualized or probed. Patients without evidence of disease and with open proximal contacts may not require a radiographic exam at this time.</td>
<td>Individualized radiographic exam consisting of posterior bitewings with panoramic exam or posterior bitewings and selected periapical images. A full mouth intraoral radiographic exam is preferred when the patient has clinical evidence of generalized oral disease or a history of extensive dental treatment.</td>
</tr>
<tr>
<td>Recall Patient* with clinical caries or at increased risk for caries**</td>
<td>Posterior bitewing exam at 6-12 month intervals if proximal surfaces cannot be examined visually or with a probe</td>
</tr>
<tr>
<td>Recall Patient* with no clinical caries and not at increased risk for caries**</td>
<td>Posterior bitewing exam at 12-24 month intervals if proximal surfaces cannot be examined visually or with a probe</td>
</tr>
<tr>
<td>Posterior bitewing exam at 6-18 month intervals</td>
<td>Posterior bitewing exam at 18-36 month intervals</td>
</tr>
<tr>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>TYPE OF ENCOUNTER (continued)</th>
<th>Child with Primary Dentition (prior to eruption of first permanent tooth)</th>
<th>Child with Transitional Dentition (after eruption of first permanent tooth)</th>
<th>Adolescent with Permanent Dentition (prior to eruption of third molars)</th>
<th>Adult, Dentate and Partially Edentulous</th>
<th>Adult, Edentulous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall Patient* with periodontal disease</td>
<td>Clinical judgment as to the need for and type of radiographic images for the evaluation of periodontal disease. Imaging may consist of, but is not limited to, selected bitewing and/or periapical images of areas where periodontal disease (other than nonspecific gingivitis) can be demonstrated clinically.</td>
<td>Not applicable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient (New and Recall) for monitoring of dentofacial growth and development, and/or assessment of dental/skeletal relationships</td>
<td>Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development or assessment of dental and skeletal relationships</td>
<td>Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of dentofacial growth and development, or assessment of dental and skeletal relationships. Panoramic or periapical exam to assess developing third molars</td>
<td>Usually not indicated for monitoring of growth and development. Clinical judgment as to the need for and type of radiographic image for evaluation of dental and skeletal relationships.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Patient with other circumstances including, but not limited to, proposed or existing implants, other dental and craniofacial pathoses, restorative/endodontic needs, treated periodontal disease and caries remineralization | Clinical judgment as to need for and type of radiographic images for evaluation and/or monitoring of these conditions |
Clinical situations for which radiographs may be indicated include, but are not limited to:

A. Positive Historical Findings
   1. Previous periodontal or endodontic treatment
   2. History of pain or trauma
   3. Familial history of dental anomalies
   4. Postoperative evaluation of healing
   5. Remineralization monitoring
   6. Presence of implants, previous implant-related pathosis or evaluation for implant placement

B. Positive Clinical Signs/Symptoms
   1. Clinical evidence of periodontal disease
   2. Large or deep restorations
   3. Deep carious lesions
   4. Malposed or clinically impacted teeth
   5. Swelling
   6. Evidence of dental/facial trauma
   7. Mobility of teeth
   8. Sinus tract ("fistula")
   9. Clinically suspected sinus pathosis
   10. Growth abnormalities
   11. Oral involvement in known or suspected systemic disease
   12. Positive neurologic findings in the head and neck
   13. Evidence of foreign objects
   14. Pain and/or dysfunction of the temporomandibular joint
   15. Facial asymmetry
   16. Abutment teeth for fixed or removable partial prosthesis
   17. Unexplained bleeding
   18. Unexplained sensitivity of teeth
   19. Unusual eruption, spacing or migration of teeth
   20. Unusual tooth morphology, calcification or color
   21. Unexplained absence of teeth
   22. Clinical tooth erosion
   23. Peri-implantitis

**Factors increasing risk for caries may be assessed using the ADA Caries Risk Assessment forms (0 – 6 years of age and over 6 years of age).**
Thank you for your attention!