INTRODUCTION TO RADIOLOGIC DIAGNOSIS OF DISEASE OF THE ORAL AND MAXILLOFACIAL REGION

---- GUIDELINES ----

Introduction

• Adherence to the following guidelines is essential for accurate radiographic interpretation and development of a differential diagnosis:

• Images/radiographs of good quality.

• Intimate working knowledge of osseous and soft tissue anatomy, radiographic anatomy, and basic nature and varieties of the pathological process that affect the tissues in the area of concern.

• When osseous lesions are being studied, the formulation of a differential diagnosis - with the disease entities arranged in decreasing order of probability, as indicated by the strength of their supporting evidence - is just as necessary as it is for the study of soft tissue lesions.

Comprehension of the multitudinous lesions, which occur in the bone, is facilitated by the fact that practically all bony lesions can be categorized in two groups, depending on whether their radiographic appearance is any of the following:

1. Completely radiolucent / Low Density (decreased bone density).

2. Totally radiopaque / High Density (increased bone density).

A factor complicating this simplified scheme is that frequently a lesion will occur with two different images, usually representing different stages of maturation.

Definitions

Osteoma: tumor of bone - some debate whether osteoma is true tumor of bone or just an exostosis.

Tumor: a swelling, a new growth of tissue which the multiplication of cells is uncontrolled and progressive; called also a neoplasm.

Neoplasm: new and abnormal growth, specifically a new growth of tissue in which the growth is uncontrolled and progressive.

Lesion: any pathological or traumatic discontinuity of tissue or loss of function of a part.

Exostosis: benign bony growth projecting outward from the surface of a bone, characteristically capped by cartilage.

Benign: one that lacks the properties of invasion and metastasis and is usually surrounded by a fibrous capsule; its cells also show a lesser degree of anaplasia (a loss of differentiation of cells and their orientation to one another) than those of malignant tumors.

Malignant: tending to become progressively worse and to result in death. Having the properties of anaplasia (loss of differentiation of cells and of their orientation to one another), invasion, and metastasis; said of tumors.
ANATOMY OF BONE / RADIOLOGY

Analysis of Bone Architecture:

Whether membranous or cartilaginous in origin, fully formed bone should be considered according to the following radiologically identifiable features. Two types of location should be sampled for a complete analysis: those which bear major stresses during life (i.e., pelvis, femora, and vertebrae) and non-weight bearing bones (i.e., skull, hands).

The former are apt to show evidence of disorders of bone production earlier. Conversely, the latter may show the features of increased bone destruction earlier and more characteristically. The latter also lend themselves more readily to detailed radiographic examination because of smaller bone diameter, freedom from excessively thick and irregular overlying soft tissues, accessibility, and ease of avoiding undesirable radiation exposure. The bones of the hands are particularly convenient in this regard.

The cortex (compacta) forms a hard shell that surrounds the medullary space, in both long and flat bones. The lacunae containing osteocytes, the nutrient system (Haversian canals, etc.) and the lamellar structure of bone surrounding the Haversian canals are visible only histologically. Radiographically, the internal (endosteal) surface of the cortex is not very well demarcated unless the cortex is abnormally thin. The external or periosteal surface is sharply defined throughout. The cortex is the major weight-supporting and shape-determining component of formed bone.

The cancellous bone (spongiosa) lies between the layers of cortex or within the cylinder of cortex in the space usually referred to as the marrow or medullary cavity and consists of a reticular network of trabeculae, or bone spicules. In long bones the number of trabeculae per unit volume normally increases toward the ends of the bone, leaving the central portion of the medullary cavity relatively free.

The spaces between trabeculae have the appearance of large cells and contain hematopoietic and supportive connective tissues and fat. Mechanically, this network of trabeculae aids in improving the structural strength of bone in addition to serving as a container for bone marrow. One can usually distinguish, in those bones where the lines of stress are relatively constant, a set of primary or major trabeculae, which are arranged parallel to the lines of prevailing stresses, and a set of secondary or minor trabeculae, which act as reinforcing elements or cross struts and run perpendicularly or obliquely to the major trabeculae.

Histologically, the trabeculae also consist of lamellar bone containing nutrient vessels and osteocytes; along their free surfaces occur single small cells (the bone-building cells or osteoblasts) and also multinucleated cells (bone-resorbing cells or osteoclasts).

The morphologic divisions of long bones include, classically, the diaphysis or shaft, the epiphysis or end, and the metaphysis, the transition between shaft and end. In growing bones the epiphysis is defined as that portion of bone that lies beyond the epiphysseal plate, a layer of cartilage where longitudinal bone growth occurs and which is vulnerable to disturbances throughout the formative years. Growth in diameter (transversely or radially) as well as the continuous bone formation and resorption throughout life are the function of the periosteum, the membrane which covers the external surface of bone cortex.
PHYSIOLOGY OF BONE / RADIOLOGY

Terminology

Bone density, the apparent radiopacity of bone, should be interpreted in dynamic terms, in relation to the process of mineralization rather than merely to the state of mineralization. Decreased density implies a relative deficiency of mineral in a given volume of bone, by virtue of insufficient calcification of existing osteoid, or by virtue of insufficient mass of osteoid capable of being calcified. Conversely, increased bone density implies a relative excess of calcified bone within a given volume, or increased calcium content within a given volume.

Porosis indicates the specific deficiency of bone matrix or osteoid. Synonyms: osteopenia, bone atrophy, de-ossification. Example: senile osteoporosis.

Malacia indicates insufficient or faulty mineralization of available osteoid regardless of whether the amount of osteoid is normal, decreased, or increased in relation to total bone volume. Example: rickets.

Decalcification, a term applicable to a chemical laboratory process rather than to an in vivo mechanism, means the "leaching out," dissolution, or isolated extraction of calcium from bone. The term also implies the state of being decalcified, presumably following such isolated removal of calcium.

Demineralization implies specific removal of whole mineral from bone or other location where it is found, or the state of bone following such a process.

Cortical bone resorption, either subperiosteal or endosteal, means thinning of cortex by loss of bone from its external or internal surfaces respectively.

Osteosclerosis is a condition of increased bone density affecting both compact and cancellous bone - that is, the entire bone material appears sclerotic or more radiopaque than normal.

Myelosclerosis signifies increased density of cancellous bone alone, while cortical bone remains within normal limits of over-all density. This may result from increased thickness or number of trabeculae, or both, in a given volume of bone and is to be distinguished from myelofibrosis, which merely denotes an increased amount of fibrous tissue in the medullary spaces and is not, per se, recognizable radiologically.

Osteopetrosis is also a condition of increased bone density, resulting from the fact that, prenatally, fetal compact bone, in the affected areas, has not been converted to cancellous bone by osteoclastic resorption. Synonyms: marble bones, Albers-Schonberg disease.

Pseudofracture is an incomplete fracture which usually extends through only a portion of the bone, the gap being filled by fibrous tissue. These fractures are indicative of abnormal softening of bone and tend to appear not only at lines of major angular or rotary stress, but also along those cortical surfaces with which an actively pulsating artery is closely associated. This association has been demonstrated arteriographically in many, but by no means all, instances. These fractures are seen in long-standing cases, and are almost invariably symmetrical. Synonyms: Milkman fractures, Looser zones.
Radiographic Interpretation

Intra-oral and extra-oral images are an indispensable diagnostic tool for pathologic conditions of the oral and maxillofacial structures. However, the indications for which imaging modality to use, and their interpretation often presents the practitioner with a multitude of challenges. The key to interpretation and the development of a differential diagnostic interpretation is to use an orderly and systematic approach.

FIRST STEP - Patient History and Clinical Examination

One of the more significant portions of successful radiographic interpretation actually begins before any images are acquired. This step involves the careful and complete evaluation of the patient's medical and dental history, as well as a clinical examination. This first step will provide the following:

HISTORY

• Patient's age
  Many pathologic conditions demonstrate a marked age range for incidence. How a certain pathologic condition will be ranked on a differential interpretation is often related to the patient's age.

• Patient's gender
  Certain lesions will present in males considerably more often than in females, while others will be just the opposite.

• Patient's ethnic background
  Patient's racial, hereditary and country of origin information can be related to the incidence of some diseases.

• Medical history
  The history of past or existing medical conditions will often provide significant clues to oral and maxillofacial radiographic interpretation. A history of systemic disorders, malignancies, previously treated lesions (and the method of treatment), as well as the patient's current medications should all be considered in the ranking of a differential interpretation.

• Dental history
  Significant clues are found in an individual's dental history. A history of symptoms, trauma, or previous treatment are just a few of the factors to consider.

CLINICAL EXAMINATION

A complete extra-oral and intra-oral examination serves two key functions:

I. Documentation of current condition
   • Symptoms
     - onset
     - severity, persistence, mode of relief
   • Alterations in eruption of teeth
   • Presence of paresthesia or anesthesia (neurologic disturbances)
   • Mobility of existing dentition
   • Appearance of overlying soft tissue (intra-oral bleeding)
   • Visible deformities
   • Functional disturbances (recent changes in occlusion)
• May serve to indicate further laboratory tests
  - CBC
  - Serum calcium
  - Serum phosphorus
  - Serum Alkaline phosphatase

II. Guide for radiographic examination
The type of imaging modality recommended and the particular views necessary cannot be determined without a clinical examination. The imaging modalities of use include:
• Conventional intra-oral radiography
• Conventional extra-oral radiography
• Panoramic radiography
• Plain film tomography
• Computed Tomography (CT and CBCT)
• Magnetic Resonance Imaging (MRI)
• Ultrasonography
• Radionuclide Imaging
Specialized techniques include:
• Arthrography
• Sialography
• Angiography and Arteriography
• Lymphography

SECOND STEP - Viewing of the Images
The environment in which one views any radiograph is extremely important when trying to distinguish subtle differences associated with different diseases processes. Equally important is the overall quality of the images.

VIEWING ENVIRONMENT
The interpretation of radiographs demands that a practitioner be able to recognize abnormal entities from normal radiographic anatomy. In addition, the fine-tuning of radiographic interpretive skills requires that very subtle differences in structure, contrast and density be identified. The following will maximize one’s interpretative skills:
• A quiet room with no overhead lighting
• Evenly illuminated view box that is masked to the film size
• High quality monitor(s)
• A "hot light" for viewing dark conventional radiographs
• A magnifying glass

QUALITY RADIOGRAPHS
The importance of good quality radiographic images cannot be over emphasized! The limiting factor in interpretation is often poor quality images, and not the skill or knowledge of the viewer. Inappropriate treatment decisions based on non-diagnostic radiographs will never be defensible in a court of law. All images should be judged for the following:
•Anatomical accuracy - does the image represent the region of interest
•Proper contrast and density
•Minimal distortion and magnification

THIRD STEP - Interpretation of Information

There are very few instances when a diagnosis is actually made from a radiograph. Most pathologic conditions in the oral and maxillofacial region share some radiographic characteristics, so use of radiographs should always be viewed as only a part of the diagnostic procedure. A sequential thought process to interpretative skills is useful.

**IS IT NORMAL?**

A thorough knowledge of normal radiographic anatomy is essential to radiographic interpretation. Equally important is knowledge of the different radiographic views and what anatomical structures are usually represented on each particular one.

**Radiographic Interpretation of Abnormal Findings**

In the interpretative process, it is often best to classify radiographic findings according to several factors. These factors include:

•Anatomic Location of a Lesion
•Localized or Generalized
•Radiodensity of a Lesion
•Shape of a Lesion
•Size
•Borders

**Anatomic Location of a Lesion**

Description of any abnormal lesion or finding on a radiograph should always be related to its relationship to other anatomical structures. This may often give clues to its origin and allow for accurate ranking on a differential interpretation. If possible, the lesion should be measured with a millimeter ruler and listed according to the view these measurements were obtained from (allows for magnification factors). Various pathologic conditions have tendencies to occur in a certain location. Examples might include:

•Ameloblastoma
  80% occur in the mandible, 70% in the posterior mandible
•Chondrosarcoma
  Found twice as often in the maxilla than in the mandible
•Benign Cementoblastoma
  Half of these are associated with mandibular first molars
•Adenomatoid Odontogenic Tumor (AOT)
  70% occur in the maxillary anterior canine region
•Lesions that are odontogenic in origin
  More likely when found superior to the mandibular canal
Localized or Generalized

Clues to the etiology and pathogenesis of a pathologic condition are often related to whether the presentation is monostotic or multifocal. As a general rule, multifocal presentations tend to be of systemic or hereditary etiologies.

Radiodensity of a Lesion

The lesion should be categorized as:

- Primarily radiolucent / low density
  - suggestive of lysis of bone
- Primarily radiopaque / high density
  - what appears opaque or uniformly dense on one image, may actually look relatively lucent on another view depending on the densities of the surrounding anatomy
- Mixed density

These terms are relative and it is important to recall that most lesions begin with a radiolucent appearance. What one observes on any particular image is a "snapshot" on a continuum of the pathogenesis of a lesion.

In addition, the trabecular pattern of the bone will influence density and be altered in certain situations:

Normal Bone Patterns (Trabeculation)

Maxilla

- fine trabeculae arranged in a lace-like pattern
- the trabecular arrangement produces smaller marrow spaces than seen in the mandible (of the same person). The finer network of trabeculae may vary from 1 mm to 3-4 mm.

Mandible

- fewer, courser trabeculae with wider marrow spaces. The trabeculae tend to run horizontally.
- in many mandibles, there is marked trabeculation around the roots of the teeth, but the pattern apical to the roots is much less patterned and may actually be devoid of any trabeculation.

Changes in trabecular patterns

- Changes in number and thickness are often associated with systemic disorders:
  - decreases in number and/or thinning of trabeculae:
    - Osteoporosis
    - Hyperparathyroidism
    - Paget's Disease
  - increases in number and/or thickening of trabeculae:
    - Osteopetrosis
- Changes in size and distribution:
  - sometimes seen in the internal aspects of a lesion with characteristic appearances:
    - Hemangiomas
    - Odontogenic Myxomas
Ameloblastomas
Odontogenic Keratocysts

- Changes in patterns:
  - "Sunburst" (Osteogenic Sarcoma)
  - "Ground Glass" (Fibrous dysplasia)
  - "Cotton Wool" (Paget's Disease)
  - "Hair on End" (Blood dyscrasias)

Shape of a Lesion

A radiograph is a two dimensional image of a three dimensional structure. In order to accurately define the shape of any pathologic lesion, at least two radiographs are usually necessary. The second radiograph should be obtained at right angles to the first. The shape of a lesion often provides a clue to its origin and what it is. For example:
- "Ball-shaped" buccal and lingual expansion of the mandible is common in cemento-ossifying fibromas
- Symmetrically rounded periapical radiolucencies are indicative of a cystic process
- "Saucer" shaped erosions of cortical bone tend to indicate that the lesion originated in the soft tissue and is invading the bone

Size of a Lesion

The size of a pathologic lesion of the oral and maxillofacial region is interrelated to both its shape and anatomic location. Care must be exercised when referring to the size of a lesion obtained from a radiograph to compensate for any magnification present for that type of imaging modality. The size of a lesion is a significant radiographic finding for several reasons, such as:
- Bony expansion
  - Present or absent
  - Facial, lingual, or both
  - Cortical bone intact or perforated
- Displacement of teeth and other anatomic structures
  - Less aggressive benign lesions
- Root Resorption (anatomic locations and the lesions effects)
  - In general, benign and less aggressive lesions tend to displace and resorb tooth structure
  - Malignancies and long standing infections tend to resorb teeth
- Treatment planning considerations
- Changes in size over time

Borders of a Lesion

The radiographic appearance of the borders surrounding any lesion is a key indicator of a lesion’s type and behavior. There are several features of the borders that should be considered:
- Unilocular
  - Often associated with less aggressive benign lesions
  - Caution should be applied because many multilocular lesions originate as radiographically unilocular
• Multilocular
  - may be associated with more aggressive types of lesions

• Definition of the margin or border
  - a range of definition is assigned to some lesion’s radiographic appearance (generalities):
    * Well defined (demarcated)
      - often seen in slow growing benign lesions and cystic lesions
    * Defined
    * Poorly defined
      - often seen in inflammatory lesions and malignant tumors
      - Also seen in several developmental entities

• Radiolucent zones at the periphery
  - benign lesions will often have a radiolucent (reactive) rim or layer just within the border of a bony lesion

• Cortication
  - a range of cortication can be evident and many times is indicative of a cystic or slow growing benign lesion (encapsulation)

"RED FLAGS"

There are several radiographic findings that should always be considered seriously and necessitate further investigation. These findings are not pathognomonic for any specific pathologic condition and may indeed be present in a totally benign lesion. However, certainty is never assured, and confirmation (usually provided by biopsy) is indicated.

Poorly defined radiolucency

Due to the rapid and irregular growth characteristics of malignant lesions, the borders are often very poorly defined. The growth is relatively fast and the surrounding bone tissue does not have time to react against the insult (like a corticated border). In addition, lesions that produce internal calcifications are generally found to represent a benign process (exception = osteogenic sarcoma). While radiolucent lesions may be either benign or malignant, combining other indicators will be helpful in the identity of a lesion.

Unilateral widening of the PDL space

Unexplained, symmetrical unilateral widening of the periodontal ligament space can be one of the initial signs of a malignancy. When this finding is identified on a radiograph, efforts to identify the possible cause should always be initiated (occlusal analysis, periodontal assessment, pulpal diagnosis)

Floating tooth

Malignant lesions can advance through the alveolar process quickly, leaving behind a relatively undisplaced tooth, "floating" in a soft tissue mass. Recognize that periodontal disease can present in a very similar manner, and great care should be exercised at determining the etiology of such a radiographic finding.
**Cortical perforation**

Due to the generally slower growth patterns of benign lesions, they will tend to expand bone at the periphery of larger lesions. The periosteum at the leading edge of expansion may lay down new bone in layers giving rise to an "onion skin" appearance. Malignant lesions are more destructive and will typically not cause expansion, will perforate cortical bone, and will extend into the surrounding soft tissues when sufficient size is attained.

**"Spiked Roots"**

Root resorption is a common finding with many benign and malignant lesions of the oral and maxillofacial structures. When root resorption occurs with benign lesions, it tends to be blunt and occurs at that portion of the root that is in contact with the lesion. Malignant lesions often leave the root surface unaffected, but when resorption occurs, they tend to affect the lateral aspects of the roots and leave the root length relatively intact. This gives the root a "spiked" or thinned appearance.

**RADIOLOGIC SIGNS OF RADIOLUCENT BENIGN OR INFLAMMATORY LESIONS -- slow-growing**

- **Borders:** well-defined, smooth, sclerotic, distinct, or scalloped.
  (If multilocular radiolucency, indicates aggressive process.)

- **Resorption of roots of teeth**
  Usually a benign lesion or inflammatory lesion.
  - Examples: Chronic inflammatory process at apex of tooth, ameloblastoma, central giant cell granuloma, and chondroma.
  - **ameloblastoma:**
    moderately-sized well-delineated borders (hyperostotic) resorption of roots as result of pressure expansion of neoplasm.
    some malignant lesions cause resorption of tooth roots.
-If no resorption, it indicates an extremely aggressive, rapidly growing neoplasm.  
**Example:** Osteoblastic osteogenic sarcoma of maxilla.
Large radiolucent lesion with small amounts of bone within tumor margins are infiltrated, and tumor has broken from bone. (Sarcoma in the jaw sometimes destroys the bone unequally, so that it penetrates into the substance without effacing everything in its path). Roots of teeth are only slightly resorbed.

![](image1)

- **Divergence and Migration of Teeth**
  - May be seen in benign, aggressive expanding lesions.
  **Example:** Central Giant Cell Tumor of maxilla with divergence and migration of teeth.

![image2]

- **Extent and Expansion of Benign Radiolucent Lesion.**
  - Well-circumscribed, confined by cortex or periosteum.
  - Cortical expansion of facial and/or lingual plates of bone
  - compatible with benign process, but aggressive.
Example: Ossifying Fibroma
smooth well-marginated, expansile lesion.
several small flecks of calcification are present within the area (fine, diffuse
distribution).

RADIOLOGIC SIGNS OF MALIGNANT RADIOLUCENT LESIONS -- Rapid Growing

• Borders: Indistinct or absent.
  Appearance: Moth-eaten, permeated, mottled, floating tooth phenomenon.
  (Permeated: the act of spreading through or penetrating a substance, tissue or
  organ.) (Mottling: condition of spotting with patches of color.)

• Cortical erosion and destruction.
  Example: Central Squamous cell carcinoma -
  Rare tumor usually seen in mandible.
  An ill-defined area of bone destruction which tends to enlarge concentrically.

• Appearance of Malignant Lesions
  - Lesions extend along medullary spaces rapidly.
  - Many times has permeated, mottled or "moth-eaten" appearance.
    (Permeation: The act of spreading through or penetrating a substance, tissue,
    or organ, as a disease process, such as cancer.)
  - Radiolucency may completely surround roots of teeth (floating tooth appearance).
  - Mottled: Condition of spotting with patches of color.
• Cortical Erosion
  - Erosion of cortices with an unconfined soft tissue mass usually indicates a malignant process.
  - Benign lesions occasionally erode cortices.
  - Irregular cortical erosion usually indicates malignant disease of surface epithelial, mesenchymal or salivary origin.
  - Mesenchymal (me-seng ki-mal). The meshwork of embryonic c.t. in the mesoderm from which are formed the c.t. of body, and also blood vessels and lymphatic vessels.
  - A "cupping-out" of the surface of an edentulous ridge associated with an ulceration of the overlying oral mucosa is suggestive of squamous cell carcinoma.
  - Example Squamous cell carcinoma arose in soft tissue of third molar region and extended by direct spread into the mandible. Note the gross irregularity of margins of the lesion with finger-like processes of bone destruction extending into bone (infiltration). No bone seen within the radiolucent area with no other change in mandible.

![Radiographic Image](image.png)

**RADIOLOGIC SIGNS OF RADIOPAQUE BENIGN OR INFLAMMATORY LESIONS**

• Calcification (organized homogenous distribution)
• Radiolucent with central opacities (less commonly malignant).
• Diffuse (widely distributed) ground glass appearance.

Examples of organized, focal or homogenous distribution of calcifications:
  - Osteoma
  - Complex odontoma
  - Cementifying/ossifying fibroma
  - Focal sclerosing osteomyelitis

Example of Benign Radiopaque Lesion: **Complex Odontoma**
  - Appearance of an irregular mass of calcified material surrounded by a narrow band with a smooth outer periphery.
Example of Benign Radiolucent Lesion with Radiopacities Within Lesion

**Calcifying and Keratinizing Epithelial Odontogenic Cyst**

- Slow-growing, completely benign condition.
- Cyst-like radiolucency containing quite distinct radiopaque foci.

**Diffuse Ground-glass Appearance of Benign Radiopacities**

Often seen in metabolic diseases such as:

- Hyperparathyroidism
- Paget's Disease
- Fibrous Dysplasia
- **Paget's Disease**
  - Ground-glass appearance: small marrow spaces surrounded by indistinct trabeculae.
  - Loss of lamina dura is also a feature.
- **Hyperparathyroidism**
  - Marked reduction in radiodensity of bone.
  - Absence of lamina dura.

**MALIGNANT RADIOPAQUE LESIONS -- RAPID GROWING**

- Disorganized, irregular, no pattern of distribution.
- Streaking or whirling pattern.
- All above may be indicative of a malignant radiopaque process.

**OTHER SIGNS OF MALIGNANT LESIONS - RAPID GROWING**

- Sudden Loosening of Teeth
- A malignant or metabolic process should be suspected with sudden loosening of teeth.
  - Widened p.d.l. (evidence of loosening).
    - Generalized
    - Localized
      - Example: localized p.d.l. space widening of 2nd premolar in chondrosarcoma.
  - Tooth extrusion could indicate a variety of things
    - More commonly it indicates supra-eruption caused by missing opposing teeth; however, could be a variety of other causes including benign and malignant processes such as osteomyelitis, trauma, and malignant neoplasms.

**Periosteal Reaction**
- Laminated periosteal reaction (onion skinning). Often found in inflammatory reactions.
- Radiating bone spicules (sun-ray reaction).
- Codman's triangle - appearance highly suggestive of osteogenic sarcoma.
  - Osteogenic Sarcoma: (Example of sun-ray periosteal reaction.)