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Review of Radiographic Technique and Interpretation of the Equine Skull

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Acquisition and interpretation of equine skull radiographs is notoriously difficult. However, by dividing the skull into anatomic regions and considering the radiographic appearance of various pathologic changes that occur in these regions, the process of evaluation becomes simpler. This report aims to review acquisition of skull radiographs and radiographic appearance of various diseases in order to aid the equine practitioner in evaluation of skull radiographs. Authors' address: Department of Environmental and Radiological Health Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, 300 West Drake, Fort Collins, CO 80523; e-mail: myra@colostate.edu. *Corresponding author.

1. Introduction

Obtaining diagnostic quality radiographs of the equine skull and interpreting the findings can be an intimidating task. The variation in degree of attenuation of x-rays by materials within the skull, from air in the sinuses to enamel in teeth, requires finesse with exposure technique. Also, different structures being evaluated require somewhat individualized radiographic views. To obtain diagnostic radiographs, it is helpful to have a compliant patient during the radiographic examination. Once good quality radiographs have been made, there is the next hurdle of interpretation. The complexity and overlap of the anatomic structures within the equine skull result in this being a challenging area of interpretation for everyone from the general practitioner to experienced radiologists. However, by breaking the skull down into several anatomic parts, applying general principles of radiographic interpretation, and learning to recognize the typical radiographic appearance of common pathologies affecting the equine head, accurate evaluation of equine skull radiographs becomes less daunting.

2. Radiographic Technique

Portable x-ray machines and standard plates are sufficient for most skull radiographs. If available, large plates are helpful for including more structures in the image, and in-house x-ray machines with greater mA capabilities are useful for denser structures such as the cranial vault and dorsoventral views. Sedation is generally recommended, except in cases in which trauma to the skull results in a neurologic status unsafe for sedation. Not only does sedation limit motion artifact and reduce exposure to personnel by means of fewer retakes, it also generally causes the horse to lower its head, easing the acquisition of images. The horse's standard halter should be replaced with a rope halter during image acquisition to reduce superimposition and metal artifacts on the radiograph. Standard safety equipment for per-

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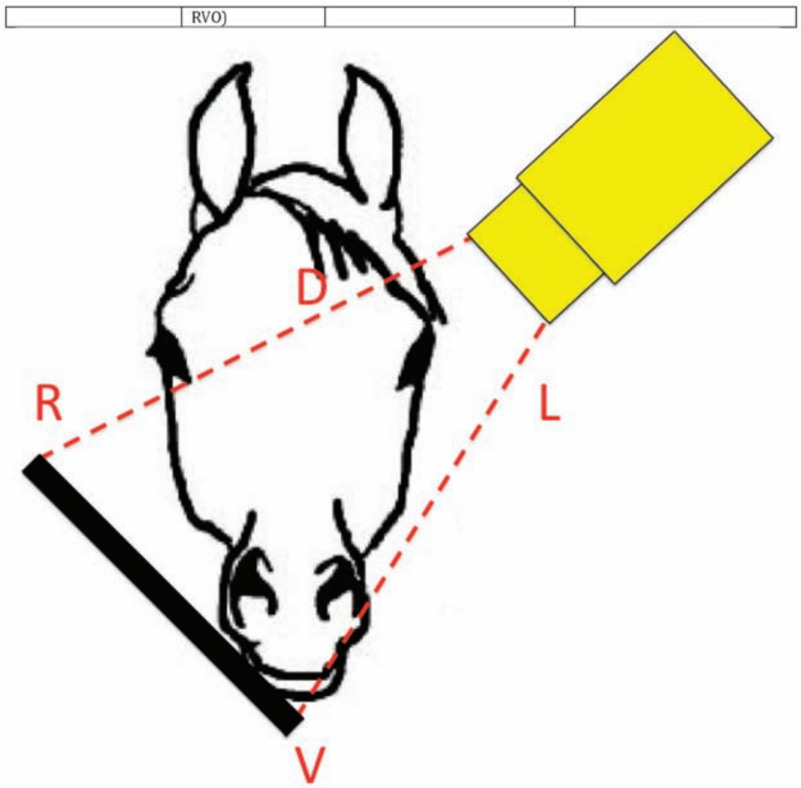

Fig. 1. Positioning for a left dorsal-right ventral oblique (LD-RVO) radiograph, highlighting the right dorsal and left ventral anatomic structures (image courtesy of Dr. Kurt Selberg).

sonnel includes lead gowns, thyroid shields, and dosimeters for everyone in the room as well as lead gloves and/or long plate handles to minimize hand exposure for the plate holder.

Proper labeling of the radiograph is essential for accurate interpretation. For dorsoventral views, markers are needed to distinguish left from right. For dorsoventral or ventrodorsal oblique views, markers should be placed to demonstrate the laterality of the structures highlighted. For example, in a left dorsal–to–right ventral oblique view of the nasal cavity, the right maxillary and frontal sinuses and right side of the nasal cavity will be highlighted dorsally; therefore, a right marker should be placed on the top of the plate (Fig. 1). The opposite is true for a left dorsal–to–right ventral oblique view. Mitchell markers, which contain beads that fall to the bottom of the marker, are helpful for determining how the plate was positioned relative to the ground. When looking for fluid lines in the sinuses, the fluid lines should be in the same plane as the beads in the Mitchell marker.

The areas of the skull to be examined can be divided into four sections: (1) incisive region (rostral skull), (2) nasal cavity, maxillary cheek teeth, and paranasal sinuses, (3) horizontal mandible, and (4) caudal skull and cranial vault, which includes temporomandibular joint and tympanohyoid articulation. Table 1 provides a brief summary of the radiographic views recommended for each anatomic section. For a more complete description of radiographic technique, the reader is directed to texts such as *Techniques of Veterinary Radiography* or *Textbook of Veterinary Diagnostic Radiology*.[1,2]

3. Common Pathologic Findings by Anatomic Region

Incisive Region Fractures

One of the most common reasons for radiography of the rostral skull is for evaluating fractures. Fractures in this region are particularly common in younger, curious horses that are mouthing stall doors or other fixed objects and become startled, pulling back and causing a fracture of the alveolar bone[3] and often extending into the incisive bone, maxillary bone, or incisive portion of the mandibular bone. The most useful radiographic projections in this case are intra-oral views, because they eliminate the overlap of incisors (Fig. 2). The affected incisors are generally displaced rostrally. Fractures of the rostral mandible can extend caudally to the diastema and to the level of the mandibular premolars, which, if incomplete, can be difficult to fully visualize radiographically.[2]

Neoplasia

Neoplasias of the rostral skull are rare and generally benign. The most common tumors of the rostral skull

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Table 1. Radiographic Views of the Equine Skull by Anatomic Region

Anatomic Area	Standard Radiographic View	Additional Radiographic Views	Notes
Incisive region	Lateral Dorsoventral	Intra-oral dorsoventral (maxillary incisors) Intra-oral ventrodorsal (mandibular incisors)	Intra-oral an excellent tool to eliminate overlap of mandibular and maxillary incisors.
Nasal cavity, maxillary cheek teeth, paranasal sinuses	Lateral Dorsoventral Right dorso 60° lateral-left ventrolateral oblique (RD60-LVO) Left dorso 60° lateral right ventrolateral oblique (LD60-RVO)	Right dorsal 15° lateral left ventrolateral oblique (RD15-LVO) (maxillary sinus and cheek teeth) Left dorso 15° lateral right ventrolateral oblique (LD15-RVO) (maxillary sinus and cheek teeth)	Both obliques should be obtained for comparison purposes. RD60-LVO projects left side dorsally. Left marker placed on top of plate. LD60-RVO projects right side dorsally. Right marker placed on top of plate.
Mandible (Horizontal rami and mandibular cheek teeth)	Lateral Right dorso 45° lateral left ventrolateral oblique (RD45L-LVLO) Left dorso 45° lateral right ventrolateral oblique (LD45L-RVLO)		RD45-LVO projects right mandible ventrally. Right marker placed on bottom of plate. LD45-RVO projects left mandible ventrally. Left marker placed on bottom of plate.
Caudal skull (cranial vault, temporomandibular joint, tympanohyoid articulation)	Lateral Dorsoventral Right dorso 60° lateral-left ventrolateral oblique (RD60-LVO) Left dorso 60° lateral right ventrolateral oblique (LD60-RVO)	Rostral 45° ventral 30° lateral-caudodorsalateral oblique (R45°V30°L-CdDLO)	R45°V30°L-CdDLO allows greater individual evaluation of temporomandibular joints and avoids the need for anesthetized dorsoventral views.

From References 1, 2, 4, and 14.[1,2,4,14]

are adamantinomas and osteomas.[3,4] Osteomas typically have a well-defined mineral opacity, occur on midline, and are slowly expansile.[3,4] Adamantinomas (also known as epidermoid cysts) are expansile, resulting in unilateral enlargement of the maxilla or mandible. They often have multiple cystic cavities with thin mineral cortices.[3,4] Unlike the appearance of benign neoplasms, malignant bone tumors such as osteosarcoma typically have less well-defined margins and can cause bone lysis, irregular proliferative new bone, and soft tissue swelling. Similarly, malignant soft tissue tumors also can cause bone lysis and proliferation as well as a soft tissue mass.

4. Nasal Cavity, Paranasal Sinuses, and Maxillary Cheek Teeth

Dental Conditions

Infection of the maxillary cheek teeth can be challenging to detect. The osseous changes adjacent to the affected tooth root can be subtle. Tooth root infections in the rostral cheek teeth are often seen with adjacent osseous sclerosis.[3] Widening of the periodontal space, changes in the shape of the tooth root, and small root fragments are radiographic indicators of infection. In the caudal cheek teeth, the roots lie in close association with the maxillary sinus, so fluid or soft tissue can be seen in the maxillary sinus in association with tooth root abscesses. If there is enough fluid present in the sinus, the tooth roots can be obscured, making detecting dental disease more difficult. Removal of fluid can help to better evaluate the tooth roots.[4]

Other changes that can be seen include periapical lucencies, facial swelling, and fractures of the crown.[5] Nasal discharge is not uncommon if the dental disease of the caudal cheek teeth results in sinusitis. An accumulation of purulent debris or impacted feed material can result in a mixed soft-

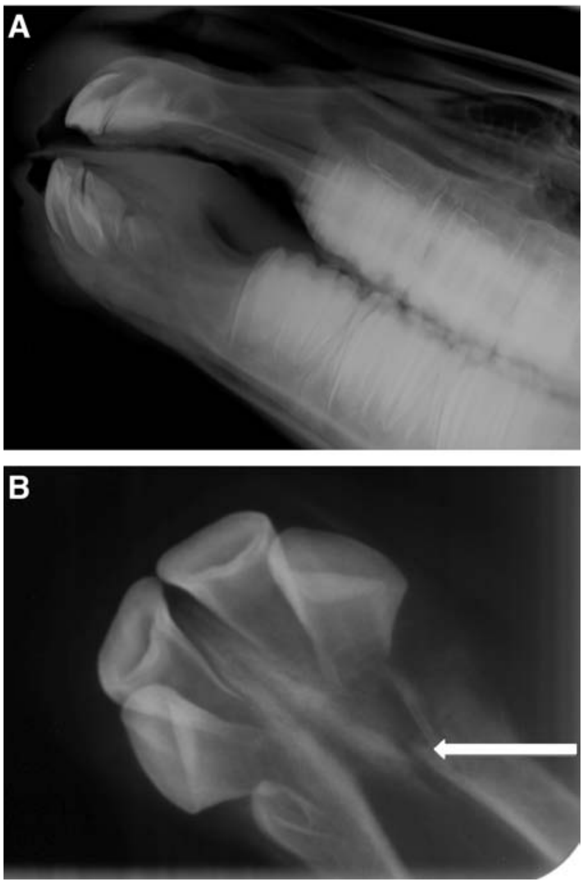

Fig. 2. A, Lateral radiograph of the incisive region. The fracture is difficult to assess due to superimposition. B) Intraoral radiograph of the mandibular region of the same horse. The oblique mandibular fracture is clearly visualized.

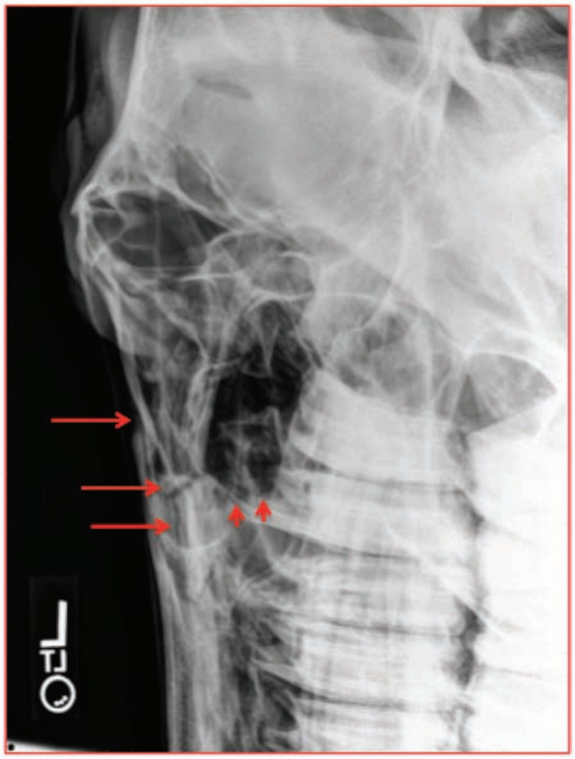

Fig. 3. Right dorsal–left ventral oblique radiograph of the paranasal sinuses. Comminuted fractures of the frontal, nasal, and maxillary bones are present (long arrows). Fluid lines are seen in the maxillary sinus (short arrows). Note the Mitchell marker on the bottom left of the image. The small beads are in the same orientation as the fluid lines.

tissue and gas opacity. In chronic cases, mineralization of inspissated material can occur. Draining tracts are less common with maxillary cheek teeth than mandibular teeth.

Dental conditions other than infection that can be appreciated include wave mouth, hooks, malocclusion, absence of teeth, and supernumerary teeth.

Sinusitis

In a study of 167 horses diagnosed with paranasal sinus, facial disease, or nasal disease, 32 had primary sinusitis,[5] which was the second most common finding after dental disease. Primary sinusitis can be bacterial or fungal and is often secondary to upper respiratory infection.[4] Common radiographic signs of primary sinusitis include variable amounts of free fluid in the maxillary and/or conchofrontal sinuses, which results in air-fluid lines, diffuse increased soft tissue opacity throughout the entire maxillary sinuses, septal deviations, and bony expansion.[5] When possible, removing fluid from the sinuses and repeating radiographs may help identify polyps or other soft tissue irregularities associated with chronic sinusitis.

Fractures

Depression fractures from trauma are the most common fractures of the frontal, nasal, maxillary, and lacrimal bones.[3–5] Multiple oblique views of varying obliquity may be required for complete evaluation of the extent of the fractures. Acute fractures will have sharply marginated fracture lines and bone fragments. Generally, there is associated increased external soft tissue swelling as well as increased soft tissue opacity within the adjacent paranasal sinuses due to hemorrhage and blood clots (Fig. 3).

Healing fractures will have irregular margins, and the fracture lines will become less distinct. The amount of soft tissue within the sinuses should decrease with time as the hemorrhage is resorbed. If fluid remains in the sinus after 2 to 3 weeks, secondary sinusitis should be suspected.[4] If a draining tract persists, sequestrum formation should be considered. A sequestrum will appear as an individual fragment of bone, separated from the surrounding bone by a lucent area caused by bone lysis. Another potential complication of fracture healing is infection. If bone fails to heal in a normal time line and there is periosteal proliferation

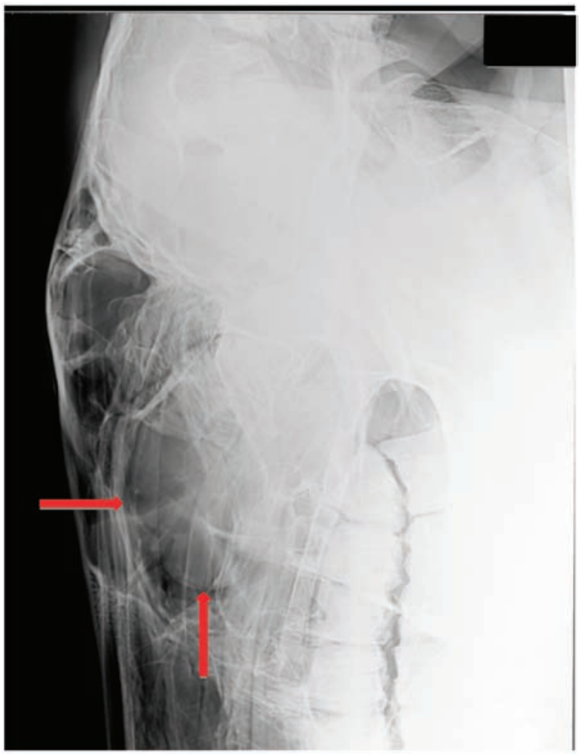

Fig. 4. Lateral radiograph of the paranasal sinuses. The ethmoid hematoma is characterized by a well-defined, smoothly marginated soft tissue opacity adjacent to the ethmoids (arrows).

and excess sclerosis and/or lysis surrounding the fracture site, then osteomyelitis is likely.

5. Sinus Cysts and Progressive Ethmoid Hematomas

Although sinus cysts are often thought to be a disease of young animals, there is in fact a bimodal age distribution, with horses younger than 2 years and older than 9 years more commonly affected.[6] Common clinical signs include increased respiratory noise, nasal discharge, and facial swelling.[6] Radiographic findings show a well-defined, rounded opacity in the maxillary and occasionally frontal sinus. Accompanying fluid, increased thickness of the sinus walls, septal deviation, dental displacement and mineralization are occasionally seen.[5–7] The work by Lane et al. showed sinus cysts to be true cysts, with a fluid-filled center and an epithelial lining.[5]

Ethmoid hematomas are generally smoothly marginated, well-defined masses in the region of the ethmoid turbinates (Fig. 4). Less commonly, they are found in the paranasal sinuses.[5,8,9] Ethmoid hematomas are generally unilateral, although occasionally they can expand beyond the ethmoidal septum.[8] Fluid can be seen in the sinuses from hemorrhage or secondary sinusitis. Clinical presentation is generally epistaxis, but nasal discharge from secondary sinusitis can also be seen.[4,5] Unlike fluid-filled sinus cysts, ethmoid hematomas are solid, expanding masses. One must be careful when diagnosing well-defined, smoothly marginated masses in the region of the ethmoid turbinates as superimposition of the eye can appear as a rounded mass.

When a sinus cyst is located in the turbinate portion of the frontal sinus or an ethmoid hematoma is located in the maxillary sinus, it can be difficult to distinguish one from another radiographically. In fact, it has been suggested that ethmoid hematomas and sinus cysts can have a similar pathogenesis, both resulting from submucosal bleeding,[6] although other authors dispute this theory.[8] Generally, sinus cysts are more likely to result in facial deformity and bony remodeling than ethmoid hematomas.[6,7]

6. Sinonasal Polyps

Sinonasal polyps are firm, pedunculated masses extending from the sinonasal mucosa and are typically seen in middle-aged horses.[7] They often are associated with chronic inflammatory conditions. Radiographically, they are characterized by well-defined, smoothly marginated opacities within the nasal cavity and can extend into the paranasal sinuses. Nasal discharge is a common clinical sign. Facial swelling can occur but is seen less commonly compared to neoplasia and sinus cysts.

7. Neoplasia

Neoplasia is relatively rare in the nasal passages of horses. The most common tumor type is squamous cell carcinoma, but other tumors that have been reported include adenocarcinoma, fibrosarcoma, osteosarcoma, osteoma, dental origin tumors, hemangiosarcoma, and lymphoma.[8,10] Common clinical findings are facial swelling or distortion, nasal discharge, mandibular and retropharyngeal lymphadenopathy, and, less commonly, epiphora, epistaxis, and nasal obstruction.[7,10] Neoplasia has been reported in young horses,[5,7,8] but most commonly occurs in middle-aged to older horses. Radiographic signs include bone lysis and proliferation, bony expansion, and the presence of one or more soft-tissue masses and fluid within the sinuses.[4,7] Irregular bone production seen within soft-tissue swellings or masses is the most indicative sign of neoplasia.[4]

Dentigerous cysts, which are distinctive tumors that arise from aberrant epithelial nests, are most frequently found at the base of the ear but can be seen in the maxillary region as well.[3] They are markedly radio-opaque and typically have an associated draining tract.[2,3]

8. Horizontal Mandible

Dental Disease

Alveolitis and apical infections of the mandibular cheek teeth often present radiographically, with widening of the periodontal space, irregularity of the lamina dura, bony lysis around the affected root, and adjacent bone sclerosis.[3,4] The tooth roots can

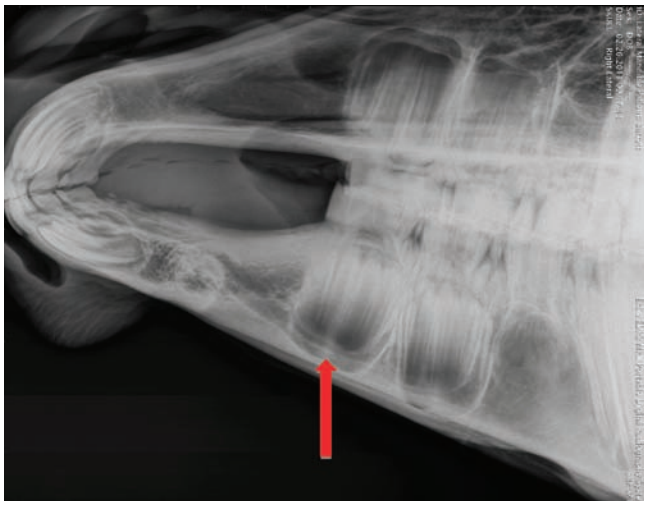

Fig. 5. Lateral radiograph of a 2-year-old filly. Note the normal lucencies surrounding the mandibular cheek teeth (image courtesy of Dr. Dora Ferris).

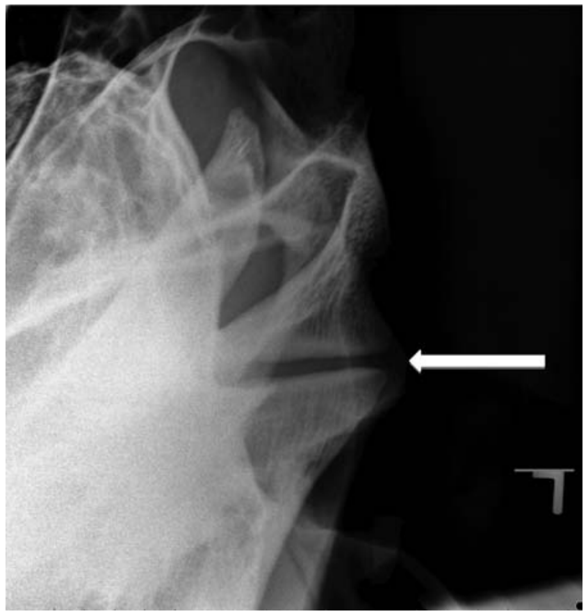

Fig. 6. Radiograph of the left temporomandibular joint, using the technique described by Ebling et al. (2009). The joint space (arrow), articular surface, and subchondral bone are clearly visualized, with minimal superimposition of other bony structures.

become misshapen. Often a firm swelling is present on the mandible with an associated draining tract. Placing a metallic probe or contrast within the draining tract can aid in following the tract to the affected tooth root.

Large, rounded, well-defined radiolucencies can be seen around the tooth roots of young horses. This generally occurs in horses from 2 to 4 years of age and occurs as the tooth is erupting and there is increased pulp vascularity. Once the deciduous caps are shed and the permanent teeth erupt, these lucencies resolve[2,4] (Fig. 5). Often, irregularities, termed “eruption bumps,” can be palpated along the ventral margin of the mandible when this occurs. These normal lucencies can be distinguished from tooth root abscesses by their smooth outline, lack of sclerosis, irregular lysis, or periosteal proliferation.

Fractures

Fractures of the horizontal rami of the mandible can be unilateral or bilateral. Unilateral fractures are more common and are generally obliquely oriented.[3] Fractures can be located anywhere along the mandible and may involve the cheek teeth, most frequently the second and third mandibular premolars.[3] Oblique radiographs separating the mandibular rami are required for complete evaluation of the mandible and to assess the possible involvement of the teeth. Tooth root abscessation is a possible sequel to fractures that extend to the alveolar bone.

9. Caudal Skull

Fractures

Fractures of the cranial vault can be difficult to appreciate radiographically. Multiple projections may be needed to obtain a radiograph that is tangential to the fracture. Fractures of the orbit may require a more steeply angled oblique (RD70-LVO or LD70-RVO) radiograph than is standardly obtained for a sinus to project the rim of the orbit with minimal bone overlap.[2] A commonly seen fracture in younger horses is at the junction of the basisphenoid and basioccipital bones. This most frequently occurs when horses fall backward, straining or avulsing the attachment of the rectus capitus ventralis minor and rectus capitus ventralis major (longus capitus) muscles.[11] This can result in hemorrhage and possible bone fragments in the guttural pouches. Care must be taken when diagnosing these fractures because the normal suture line between the basisphenoid and basioccipital bones does not close until between 3 and 5 years of age and can be mistaken for a fracture. Therefore, bone displacement or fragmentation must be present before definitively diagnosing a fracture at this location in younger horses.[11]

Temporohyoid Osteoarthropathy

Temporohyoid osteopathy causes ankylosis of the temporohyoid joint, resulting in increased strain on the stylohyoid bone and petrous temporal bone, and has been associated with head shaking, vestibular disease, and facial nerve abnormalities.[12,13] Radiographic signs include thickening and irregularity of the stylohyoid bone, thickened temporohyoid articulation, and sclerosis of the petrous temporal bone.[12] Anesthetized dorsoventral radiographs are particularly helpful for radiographic diagnosis, but caudo-rostral oblique views can be utilized if anesthesia is not possible.

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Temporomandibular Joint

Radiographic diagnosis of temporomandibular joint (TMJ) disease can be challenging due to radiographic overlap. Recently, a view providing better visualization of the articular surface and joint space was described.[14] This view, a rostral 45° ventral, 30° lateral-caudodorsalateral oblique (R45°V30°L-Cd-DLO), decreases the amount of superimposition, which is a problem on standard radiographic views (Fig. 6). Although standard views can diagnose more severe problems, such as luxation or marked fractures, the oblique view described by Ebling et al.[14] allows for more subtle changes, such as subchondral bone defects, to be evaluated.

10. Conclusions

While challenging to obtain and interpret, radiography is still the most frequently used imaging modality for diagnosing disease of the equine skull. The greatest limiting factor in obtaining an accurate diagnosis is the large amount of superimposition. Although it is recognized that advanced imaging such as CT and MRI can often provide more complete diagnostic information, they are not always readily available or may be financially prohibitive. Therefore, it is helpful to the equine practitioner to practice acquisition and assessment of skull radiographs. Although there are few pathognomonic findings for many of the disease processes, by carefully assessing the radiographic findings in conjunction with the patient's signalment and clinical presentation, severity and extent of disease and accurate differential diagnoses can be established.

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