Computed Tomographic and Ultrasonographic Examination of Equine Dental Structures: Normal and Abnormal Findings

Sarah M. Puchalski, DVM, Diplomate ACVR

Author's address: Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California, Davis, E-mail: smpuchalski@ucdavis.edu.

Take Home Message

Radiology will always remain the 'first test' in imaging the equine skull and should be considered when examining a horse suspected of having disease of the paranasal sinuses, the cheek, incisor, and canine teeth, or the temporomandibular joints (TMJ). In some cases, the practitioner should consider advanced imaging options, specifically computed tomography and ultrasound, to better define an unusual or particularly challenging dental problem.

Introduction

Radiology is a very useful tool and is often the first ancillary imaging test used when either sinonasal or dental disease is suspected (Gibbs and Lane 1987; Dixon, Tremaine et al. 1999; Dixon, Tremaine et al. 1999; Weller, Cauvin et al. 1999; Baker and Easley 2000; Butler, Colles et al. 2000; Dixon, Tremaine et al. 2000; Dixon, Tremaine et al. 2000; Tremaine and Dixon 2001; Tremaine and Dixon 2001; Barbour-Hill 2004; Dixon and Dacre 2005). It is a planar imaging modality where a three-dimensional structure is projected onto a two dimensional image resulting in superimposition of many anatomic structures, which can obscure or confuse important radiographic findings. In general, radiology has significant limitations in the evaluation of soft tissues that are partially ameliorated when the soft tissues are surrounded by air but that are exacerbated when the soft tissues are surrounded by bone. When supplementary information is necessary to accurately assess the extent of disease or when questions arise regarding the anatomic localization of the lesion, additional diagnostic imaging is indicated.

Computed Tomography (CT)

Computed tomography (CT) is anatomic cross-sectional imaging that uses x-rays and x-ray attenuation to create the image. The CT gantry houses a row of x-ray detectors across from an x-ray generator. The gantry rotates around the region of interest on the patient creating a 'cross-sectional x-ray image'. The basic physics of CT are dependent on tissue density, similar to planar radiology, but CT's cross-sectional nature eliminates superimposition of structures and dramatically improves resolution. CT is particularly useful in the skull where inherent subject contrast (i.e., large density changes between gas, soft tissue, bone and enamel) is high (Fig. 1).

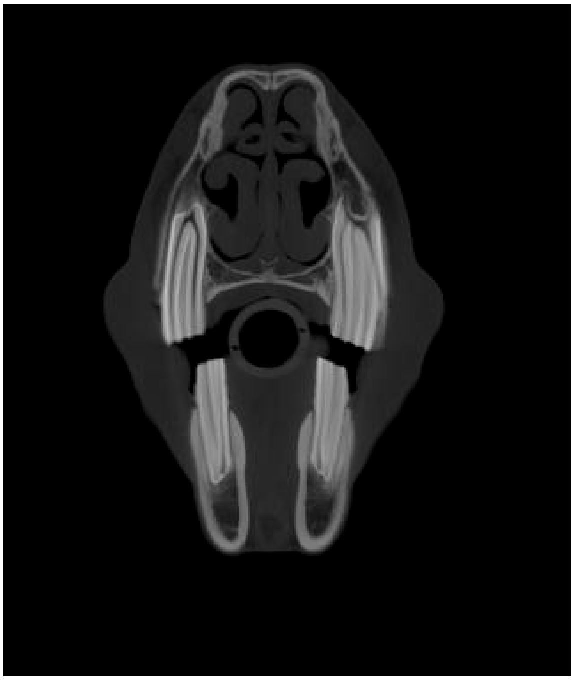

Figure 1. CT image of the rostral skull of a middle-aged horse. The anatomy of the teeth and overlying nasal passage is very clearly defined.

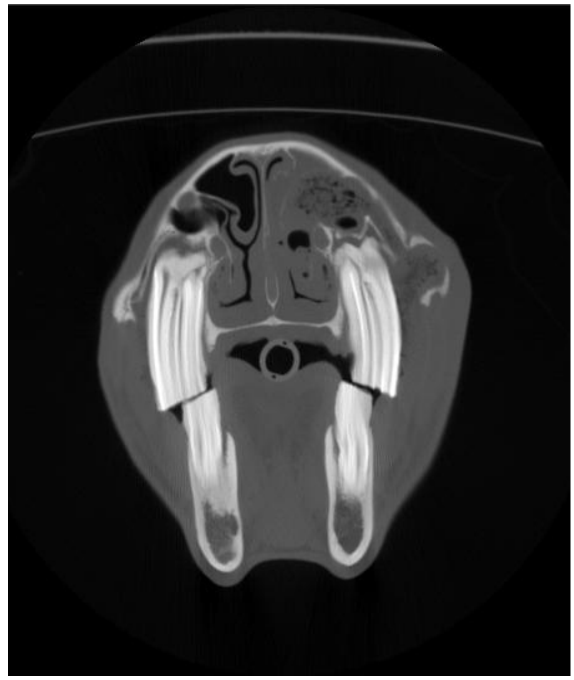

Figure 2. CT image demonstrating fragmented gas and feed material along the buccal surface of a fractured #208 cheek tooth causing communication of the oral cavity and the rostral maxillary sinus. The periodontal space surrounding the contralateral maxillary cheek tooth (cheek tooth #108) is wide and irregularly margined.

CT image interpretation is based on the principles of radiology, and so, imaging characteristics already familiar to the practitioner can be applied to the CT images. For example, widening or increased lucency of the periodontal/periapical space occurs on CT images in the same way that it occurs on radiographic images, and its presence can be interpreted in a similar manner, which is, that it most likely represents osseous resorption secondary to infection or periodontal disease (Fig. 2).

There are other advantages to CT that improve the diagnostic use of the modality. It is inherently a digital modality, and therefore, all of the advantages of digital imaging apply to it. Image-viewing software can be used to alter the window and level (digital imaging terms analogous to contrast and brightness), in addition to features such as zoom, rotate and measure. Another useful feature of CT is that the images can be reformatted into different imaging planes, even if they are initially acquired in an axial plane (Fig. 3).

The major disadvantage of CT is that the horse must be anesthetized during acquisition of the images (Fig. 4). Historically, CT scanners in use in veterinary medicine were older generation axial scanners, which required a considerable amount of time to acquire a diagnostic study. The technology has advanced recently, and many veterinary hospitals offer helical scanning technology, whereby the horse advances through the center of the

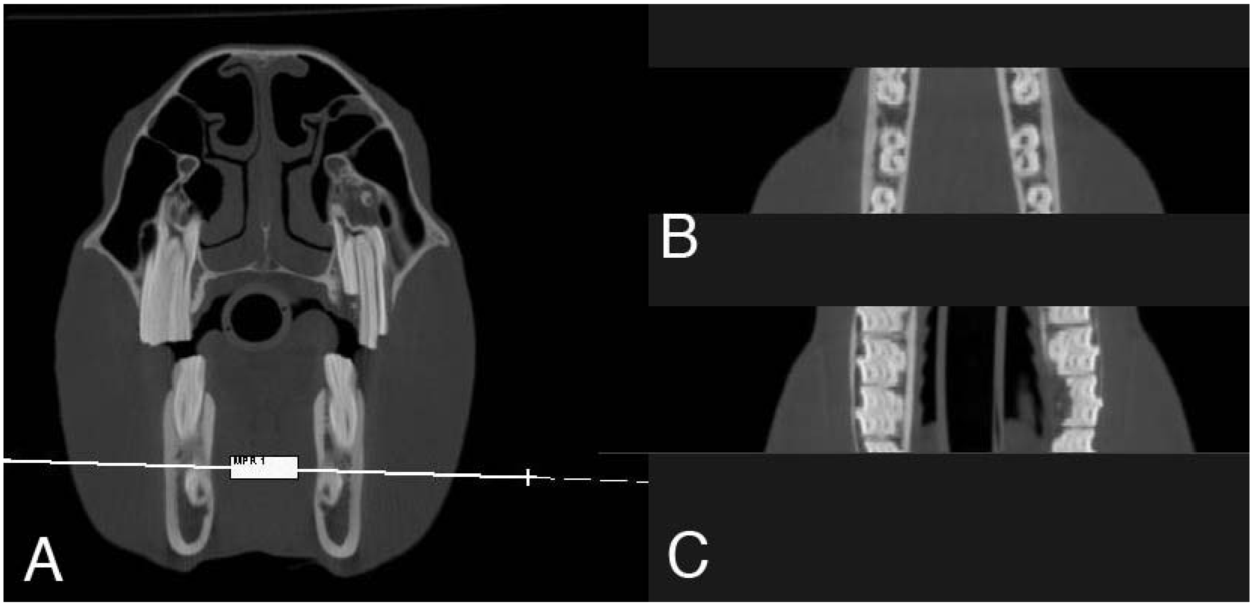

Figure 3. A. Cross-sectional CT image demonstrating a sagittal fracture of a maxillary cheek tooth. B. Reformatted dorsal plane image of the mandibular cheek teeth reserve crowns. C. Reformatted dorsal plane image of the maxillary cheek teeth demonstrating the fractured maxillary cheek tooth.

gantry as the gantry continues to rotate. This is opposed to older generation scanners where the gantry would rotate through 360° and then reset, and then the horse would advance. Helical scanning is generally capable of one slice per revolution (i.e., a slice), and the slice thickness can vary from 1 to15 mm. In the future, in addition to single slice helical scanning, veterinary centers may be able to offer multi-slice scanning where 4-16 slices can be obtained in one second. The disadvantage of general anesthesia is largely offset by the additional information gained. Often, the indicated procedure can be performed under the same general anesthetic period as the diagnostic imaging.

Figure 4. This horse is positioned in dorsal recumbency in order to scan the skull for dental disease.

There are many different reports in the literature of a variety of conditions of the equine skull that document the value of CT (Tietje, Becker et al. 1996; Warmerdam, Klein et al. 1997; Sasaki, Hayashi et al. 1999; Morrow, Park et al. 2000; Walker, Sellon et al. 2002; Lischer, Walliser et al. 2005; Quinn, Tremaine et al. 2005). One major report describes the CT findings associated with dental infections and infections of dental origin affecting the surrounding supporting structures (Henninger, Frame et al. 2003). In general, CT is indicated when secondary infections of the sinuses or paranasal bones compromise radiographic evaluation of the underlying primary problem, and when a draining tract, a supernumerary tooth, or any other dental abnormality cannot be explained by conventional radiography. CT should also be considered as a means to increase the diagnostic certainty in clinical situations where the incorrect treatment is undesirable or potentially harmful to the patient (i.e. extraction of a non-diseased tooth).

Interpreting CT images, like interpreting dental radiographs is a challenging task and should be undertaken by suitably trained personnel only after the horse has been clinically examined and after high quality radiographs have been made and evaluated. An accurate diagnosis depends on both recognizing an abnormality and then determining which disease process caused the abnormality.

To accurately detect dental abnormalities, the individual teeth and their relationship to each other must be carefully evaluated. Knowledge of dental anatomy and the life cycle of a tooth, including the changes in dental anatomy associated with development, eruption and growth wear, is of utmost importance. There are major age-related changes in the radiographic and CT appearance of hypsodont teeth that should not be misinterpreted as being caused by disease.

Ultrasound

Ultrasound is a powerful and readily available tool for the equine practitioner. Its use for evaluating dental structures is limited, however, by two major impediments. Ultrasound waves are unable to penetrate bone and dental tissue and are completely reflected by gas, and calcified tissues and air are common in the oral cavity. Ultrasound is useful, however, for evaluating soft tissues that overlie teeth and for evaluating the temporomandibular joints (TMJ)(Weller, Cauvin et al. 1999; Weller, Taylor et al. 1999).

Ultrasound is also a cross-sectional imaging modality that occurs in real time. Currently, high quality, high frequency systems are available for ambulatory or clinic based practices, which provide dramatically improved image quality. It is important to realize, however, that the diagnostic ability of ultrasound is highly operator dependent and that an in-depth knowledge of the topographical anatomy is of paramount importance in making accurate diagnoses.

Imaging Characteristics

Each individual tooth has a complicated internal architecture. Common to the structure of all teeth are cement, enamel, and dentin. All teeth have one or more pulp cavities that contain the vascular and nervous tissues, and all teeth are held fast to the alveolar bone by a periodontal ligament. The incisors and maxillary cheek teeth have infundibula. Using CT, all of these different dental tissues can be visualized.

Enamel is the densest tissue represented on CT and appears as the whitest tissue with the highest Hounsfield Unit value. Similar to its appearance on radiographs, enamel appears on CT images as an undulating dense tissue in the exposed and reserve crown, and is denser than the alveolar bone cortex that is termed the lamina dura by radiologists. It is surrounded by either dentin or cementum. In the young horse, the pulp cavity appears on CT images as a large and well-defined radiolucent space, and as the tooth ages, this appearance is lost. On CT images, dentin has a density that is intermediate between that of enamel and the soft tissues of the pulp chamber and that of the periodontal ligament. Radiographically and on CT images, cementum is seen as tissue that is hypodense to enamel. It is hyperdense to the periodontal ligament soft tissues making the two tissues distinguishable. The periodontal ligament should appear as a well-defined, thin radiolucent (hypodense) line that is smoothly margined and follows the external surface of the tooth. Recognition of this periodontal space is critically important when assessing teeth for apical infection or periodontal disease. The reserve crown becomes narrower as it approaches the apex, and the inter-dental spaces of aged horses with little reserve crown are wider than those of younger horses. The periodontal ligament of an aged tooth is much less apparent than that surrounding a young tooth, causing the lamina dura to appear to abut on to the enamel of the tooth. The pulp cavity appears as a relatively radiolucent space extending from the apex to the central portion of the tooth. When evaluating CT scans, as well as when evaluating radiographs, recognizing age-related differences among the teeth is important.

The incisive bone, maxillae, and mandible house the dental alveoli. The lamina dura is a dense shelf of cortical bone that is attached to the periodontal ligament. Outside the thin shelf of very dense bone described as the lamina dura is the alveolar bone, which is then surrounded by the trabeculae of the incisive bone, mandible and maxilla. Alveolar bone responds to both pathologic and physiologic processes by becoming sclerotic and by producing new periosteal bone. The lamina dura of a normal tooth appears as a thin, well-defined, radio-opaque line. Early radiographic and CT changes secondary to infection are loss of definition of the lamina dura and sclerosis of the surrounding alveolar bone.

The close relationship between the cheek teeth and the overlying paranasal sinuses complicates radiographic interpretation of the last four maxillary cheek teeth. Only a thin shelf of bone separates the rostral maxillary sinus from the caudal portion of the apex of the fourth premolar and apex of the first molar. Similarly, only a thin shelf of bone separates the caudal maxillary sinus from the apex of the second and third molars. Computed tomography of the maxillary arcade is particularly valuable. Although overlying sinusitis or abscess formation can lead to the misinterpretation of lucencies or sclerotic change on radiographs, CT is generally able to delineate the differences through the elimination of superimposition. Ultrasound is useful for identifying the origin of swellings or draining tracts that may accompany disease of the maxillary or mandibular arcade. Occasionally, a previously undelineated draining tract within a soft tissue swelling can be followed to its site of origin, especially if the swelling involves the mandible.

The temporomandibular joint, like most other joints, can be affected by osteoarthrosis. Radiographic changes typical of joint disease, such as joint surface irregularities, sclerosis, narrowing, malalignment, and periarticular osteophytosis, occur in the temporomandibular joint but may not be radiographically evident until clinical signs of osteoarthrosis have been apparent for some time. This articulation is easily imaged using computed tomography, and a few reports demonstrate its usefulness for diagnosing disease of the TMJ (Warmerdam, Klein et al. 1997; Weller, Cauvin et al. 1999; Devine, Moll et al. 2005). Ultrasound examination of this joint can give an accurate assessment of the joint's soft tissues and periarticular bone (Weller, Taylor et al. 1999; Rosenstein, Bullock et al. 2001). Knowledge of the regional anatomy is important in the interpretation of all modalities and particularly so for ultrasound (Weller, Taylor et al. 1999; Rodriguez, Agut et al. 2006).

An often-overlooked cause of oral dysfunction that can manifest as dysphagia or resistance to bitting is abnormality of the hyoid apparatus. Radiography of this structure is often used in conjunction with endoscopic examination of the guttural pouches. CT allows the structure to be completely evaluated by eliminating superimposition of the skull. (Walker, Sellon et al. 2002)

Discussion

The equine skull and the dental structures, in particular, have a complex structure and can be afflicted by numerous conditions. To make accurate diagnoses and to perform appropriate treatments, many steps, including a thorough clinical examination in addition to diagnostic imaging, should be taken. In some cases, when the clinical situation is complicated, routine radiography is inadequate to accurately define a problem area. In these cases, computed tomography should be considered because it provides superior resolution without superimposition that can refine the clinical diagnosis. Similarly, ultrasound has definite uses and should be considered for the evaluation of the temporomandibular joints and any soft tissue abnormalities that may not be localized specifically as a dental problem. Limitations exist with all diagnostic tests, and should be considered when recommending advanced imaging. In particular, CT has the disadvantage of usually requiring general anesthesia in dorsal recumbency, and ultrasound is unable to penetrate bone or dental tissue.

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