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**Peridental Anatomy: Sinuses and Mastication Muscles**

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**Take Home Message**

The paranasal sinuses are closely related to the caudal maxillary cheek teeth and several cranial nerve branches. Dental disease can spread to these sinuses leading to nasal discharge and the possibility of serious neurological complications. Access to the sinuses should avoid damage to the infraorbital canal and nasolacrimal duct.

**Introduction**

Peridental entities such as the paranasal sinuses and mastication muscles play important roles in dental disease processes. This presentation is intended to describe the anatomy of these subjects.

The paranasal sinuses of the horse are formed by extension of the lining of the nasal cavity between external and internal plates of several skull bones. Much of this process occurs after birth. The frontal and maxillary bones are the main ones “excavated” to form the paranasal sinuses, but also, the sphenoidal and palatine bones are involved in sinus formation. Additionally these sinuses invade the dorsal, ventral and ethmoidal conchae (turbinates). Like the nasal cavity, right and left sinuses don’t communicate. The maxillary sinus of the horse is large and divided into rostral and caudal compartments. The facial crest is a landmark for the maxillary sinuses which lie between the boney orbit and the infraorbital foramen and deep to the facial crest.

The paranasal sinuses drain into the middle nasal meatus via slit like nasal maxillary apertures that come from both the rostral and caudal maxillary sinuses. The frontal sinus of other species communicates directly with the nasal cavity, but the equine conchofrontal sinus communicates with the nasal cavity indirectly by way of the caudal maxillary sinus. While the nasomaxillary apertures are thin and cryptic, the frontal maxillary opening is a large oval passage that is easily seen. The conchofrontal sinus drains into the dorsal aspect of the caudal maxillary sinus and the small sphenopalatine sinus drains into the ventral part of the caudal maxillary sinus.

In the horse the main mastication muscles are the masseter and pterygoid muscles while the temporal and digastric muscles are of lesser significance. The masseter muscle lies lateral to the mandible while the medial and lateral pterygoid muscles attach to the medial side of the mandible. The medial pterygoid muscle is considerably larger than the lateral pterygoid muscle and the mandibular nerve passes between them. The latter muscle attaches close to the temporomandibular joint. Grinding movement of the cheek teeth is the result of synergistic action of the masseter and pterygoid muscles acting together to cause lateral/medial movement of the mandible. The masseter muscle has superficial and deep parts. The superficial part
attaches to the ventral and caudal margins of the mandible while the deeper part has more vertical fibers and attaches to the lateral side of the mandible.12

Materials and Methods

In addition to traditional dissection methods, transverse bandsaw sections of cadaver heads were made to correlate with computed tomographic (CT) images from a live horse. Lateral radiographs of hemisected cadaver heads were used to create images free of overlapping structures on right and left sides.

Results

The frontal sinus of the horse is continuous with the dorsal conchal sinus forming a conchofrontal sinus. This sinus is the most dorsal of the paranasal sinuses; the maxillary sinuses are more ventral and lateral. The conchofrontal sinus communicates with the caudal maxillary sinus via the large oval frontal maxillary opening (Fig. 1) that lies medial and slightly rostral to the bony orbit.

Figure 1. CT section of the head of a live 7 year old Warmblood horse at the level of the last cheek tooth (11). CF = conchofrontal sinus, CM = caudal maxillary sinus, VS = ventral conchal sinus, asterisk = lumen of endotracheal tube, arrows as follows, yellow = in the frontomaxillary opening, white = nasolacrimal duct, blue = facial crest, red = infraorbital canal, green = groove for great palatine artery which supplies the hard palate.
The dorsal concha was clearly attached to the other ethmoidal conchae (Fig. 2). The middle concha contained a space that opened to the caudal maxillary sinus or was not open. The ventral concha was not related to the ethmoidal conchae (Fig. 2).

![Figure 2. Split head of pony with windows cut into the dorsal concha and ethmoconcha II. I = ethmoconcha I (dorsal concha), II = ethmoconcha II (middle concha), III = ethmoconcha III, B = bulla in dorsal concha, DC = dorsal conchal sinus, F = frontal sinus, GP = guttural pouch, SP = sphenopalatine sinus, VC = ventral concha.](image)

The caudal maxillary sinus is considerably larger than the rostral maxillary sinus. The size of both maxillary sinuses is increased significantly with age as the maxillary cheek teeth shorten due to attrition. In the young animal the infraorbital canal is in direct contact with the apical part of the alveoli of the caudal cheek teeth (Fig. 3) but with age the distance between the infraorbital canal and the alveoli increases and a thin plate of bone connects the canal to the dental alveoli (Fig. 1). The alveoli of the caudal cheek teeth and the infraorbital canal form a wall that separates the rostral maxillary sinus from the more medial ventral conchal sinus (Fig. 3).

![Figure 3. Bandsaw section through the rostral maxillary sinus.](image)
Discussion

The function of paranasal sinuses is probably one of biological economy by lightening the head while at the same time providing enough size for large teeth and an adequate oral cavity for mastication of forage.\(^1\) Certainly the head would be much heavier if the sinuses were filled with solid bone. This situation is similar to a hollow aircraft wing that has a large surface area for lift but is relatively light for its size. It is unlikely that heat exchange is a significant secondary function because the sinuses lack the rich venous plexuses that are found in nasal mucosa. Thirdly, the paranasal sinuses may act as sound resonators to modulate vocalization.\(^1\)

Various methods have been used to study the complex anatomy of the paranasal sinus. Bandsaw sections of cadaver heads have been used to analyze computed tomographic (CT)\(^{10,13-14}\) and magnetic resonance (MR) images.\(^{15}\) Sinoscopy has been useful for anatomical investigation and also for diagnosis and therapy of sinusitis.\(^{16}\) One of the best ways to gain a three dimensional understanding of the paranasal sinuses is by scrolling back and forth through a series of transverse CT images of the head. Although there are several published CT studies of the equine head, the paucity of published images therein makes these publications of limited value for a thorough anatomic study of the sinuses. What is needed is an atlas of the equine head similar to the Denoix atlas\(^{17}\) of the equine distal limb. This presentation will provide a series of 36 labeled CT images of the paranasal sinus from a live horse. Live horse CT scans show a thick nasal mucosa due to filled venous plexuses. In contrast, cadaver CT sections and band saw sections have thin nasal mucosa due to lack of blood pressure.

The anatomy of the paranasal sinuses is summarized by the schematic illustration shown in Figure 4 below.
The ethmoidal conchae are for the most part small scrolls attached to the cribiform plate that separates the nasal cavity from the cranial cavity (Fig. 2). Collectively the ethmoidal conchae are often referred to as the ethmoidal labyrinth or endoturbinates. The exception is the large dorsal concha which is also designated as ethmoconcha I. The next ventral ethmoconcha is the much smaller ethmoconcha II which is sometimes referred to as the middle concha. The remaining ethmoconchae are referred to collectively as ethmoconchae III.

Dorsal and ventral conchae contain both a sinus and more rostrally a bulla (Fig. 2). Sinuses are open to the nasal cavity while a bulla is not open. In this study the space within ethmoconcha II opened into the caudal maxillary sinus or it was a bulla rather than a true sinus because no opening was found. The ventral conchal sinus is usually associated with the rostral maxillary sinus but in Fig. 1 it can be seen medial to the caudal maxillary sinus.

The maxillary sinus of the horse is better developed than in other domestic mammals. As the cheek teeth shorten due to attrition the alveolar wall surrounding them continually reshapes and the size of the maxillary sinuses increases. Therefore, the anatomy of the maxillary sinus is far more age dependent than the other paranasal sinuses but all get larger with age.

The nasolacrimal duct extends from the medial aspect of the orbit to the floor of the nostrils. Most of its course is in the maxillary bone where it protrudes into the maxillary sinus (Fig. 1). It could be damaged by trephine holes made to access the maxillary sinus. Likewise, great care should be taken to avoid damage to the infraorbital canal when repelling caudal maxillary cheek teeth (Fig. 3).

The sphenopalatine sinus (Fig. 2) is considerably smaller than the other paranasal sinuses but it is in close proximity to the optic nerve dorsally and cranial nerves 3, 4, 5, and 6 lie lateral to this sinus. In older animals this sinus is larger and more complex.

The boney surfaces of the temporomandibular joint (TMJ) appear incongruent when viewed as “bare bones”. The space between the mandibular condyle and the articular facet on the temporal bone is filled with a fibrocartilagenous disc. The equine TMJ is designed to permit lateral to medial movement of the mandible. This sideways movement is considerably greater than rostrocaudal motion during the chewing cycle.

The masseter and pterygoid muscles primarily act to close the mouth but they also cause sideways (lateral/medial) movement of the mandible. The masseter muscle pulls its mandibular insertion in a lateral direction because the origin on the facial crest is lateral to the insertion on the mandible. Likewise, the pterygoid muscle pulls its mandibular insertion in a medial direction because the origin on the pterygoid bone is medial to the insertion on the mandible. Therefore, each masseter muscle acts in concert with the contralateral pterygoid muscle to pull the mandible towards the side of the contracting masseter muscle. Much has been said about the narrow mandible of the horse (anisognathism). While there may be a variety of reasons for this condition, one result is a greater lateral to medial spread of the attachments of the masseter muscle making it more efficient for pulling the mandible laterally.
The sternomandibularis\textsuperscript{11} muscle is not a mastication muscle because it is not involved in the chewing cycle. However, when the rostral caudal incisor displacement exam\textsuperscript{20} is performed, the sternomandibularis muscle causes caudal displacement of the mandible as the atlanto-occipital joint is extended.

References


Dental Anatomy

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Dental Embryology

In the equine fetus, a band of epithelium along with the underlying mesenchyme infolds into the primitive oral cavity and forms a series of buds that will later develop into the deciduous teeth. A further, smaller protrusion develops off of the incisor and premolar deciduous teeth buds, which becomes buds of the permanent teeth. Clinically important details from dental embryology include the fact that the tissue initiating tooth formation is epithelial in origin and consequently, animals with generalised epidermal dysplasia have absent or dysplastic teeth in addition to possibly having dysplasia of their skin, tail, mane and their hooves. Also of clinical importance is that if an incorrect number of buds i.e. too few or too many develop, the animal will subsequently have anodontia (no teeth) if no buds develop; hypodontia if a reduced number of buds are present or supernumerary teeth, if an increased number of buds develop. Within the dental buds, ameloblast (epithelial-derived) cells develop which produce enamel, along with two types of mesenchymal cells, i.e. odontoblasts which produce dentine and cementoblasts which produce cement(um). Interaction between the ameloblasts and odontoblasts initiates tooth formation.

The alignment of these buds is also critical. If the dental buds are displaced, the teeth that subsequently develop from them will also be displaced. This reason for dental displacement is additional to the more common cause, i.e. dental displacement caused by overcrowding of teeth during eruption. The epithelial-derived component of the dental bud forms the enamel organ and this structure determines the final shape of the teeth. In equine teeth, in contrast to brachydont (e.g. human) teeth, the enamel organ has marked infolding of its periphery, especially in mandibular cheek teeth as well as the single infundibulum (enamel infolding) present in incisors and the paired infundibulae in the upper cheek teeth. Developmental irregularities in the orientation, shape or size of the enamel organ will cause the enamel structure of the teeth and subsequently of the dentine and cementum to be abnormal, i.e. dysplastic. Genetic abnormalities of enamel, dentine and cementum proteins also cause dental dysplasia, but these have not been studied in the horse.

The blood supply to the developing tooth is derived from a fleshy structure termed the dental sac that surrounds it. It is now known that a blood supply also perforates the apical aspect of the infundibulum in young equine cheek teeth and these apical infundibular blood vessels may remain for a couple of years after dental eruption.

Equine Dental Tissues

Enamel

Equine enamel is in general similar to enamel in other species, being a hard and dense substance composed of 96-98% minerals. Because it is inert and acellular once formed, it is then basically a
dead calcified material and cannot repair itself. The structure of equine enamel has been described by Kilic et al. who have divided it into two main types. Equine type 1 enamel which is the main constituent of the cheek teeth, consists of parallel rows of prisms lying between parallel, dense interprismatic plates of enamel (Fig. 1). This type of enamel has evolved to be extremely hard, to allow for the very prolonged mastication of fibrous food (up to 18 hours per day) by the horse. However, because of the parallel orientation of its prisms and interprismatic enamel it is more susceptible to developing fractures than the other main type of enamel, i.e. Equine type 2 enamel. The latter type of enamel solely consists of prisms (rounded on cross section) which are oriented in three directions. It has a “spaghetti-like” appearance as the prisms interweave with each other in the 3 different planes. This type of enamel is softer than Equine type 1 enamel but because of the absence of any parallel planes within its structure, it is very resistant to cracking. It is therefore not surprising that the equine incisors are largely composed of Equine type 2 enamel because they are relatively small and have little support from the adjacent incisors, yet can pull fibrous food vigorously for prolonged periods each day without developing spontaneous fractures (unlike the cheek teeth).

Figure 1. Electron microscopy of Equine Type-1 enamel.

Enamel is produced by the ameloblasts at the apical aspect of the developing teeth and when the enamel is fully developed (usually about the time of dental eruption) the ameloblasts die off, and as noted no further regeneration of enamel can now occur. Later on in dental development and following tooth eruption, cementum is deposited at the apical aspect of the enamel and these enamel free areas are the true roots of the equine teeth. Another difference in equine as compared to brachydont teeth is the fact that the (shiny) enamel on the sides of equine clinical (erupted) crown is usually not visible because it is covered by a layer of dull, often stained cementum, an exception being the rostral/vestibular aspect of the incisors where the cementum becomes worn away while prehending food, revealing the underlying shiny, white enamel.

**Enamel Infolding and Infundibular Enamel**

The cheek teeth have evolved to become very efficient at grinding tough fibrous food and instead of having a single layer of enamel around the periphery of the cheek teeth (like incisor teeth) the lower cheek teeth in particular have very extensive infolding of enamel that protects the softer cementum and dentine. du Toit et al have shown that the ratio of peripheral enamel length to tooth perimeter in mandibular cheek teeth is 1.87 (indicating much infolding of enamel),
compared to a value in maxillary cheek teeth of 1.48; however, the maxillary cheek teeth also have infundibular enamel that compensates for their reduced infolding.\textsuperscript{4} Normal infundibulae can be up to 89 mm long in 4-year-old horses to as low at 2 mm in 30-year-old horses which on average infundibular length being a mean of 82\% of the total dental crown length; however, in individual cheek teeth and horses, they may be relatively much shorter.\textsuperscript{1} Thus with age either one or both infundibular can wear out (often in the 09 or 10) causing the adjacent unsupported primary and secondary dentine to wear very fast and the tooth to become hollow. Eventually this is a feature of most old teeth and this form of wear has been termed \textit{senile excavation}. Likewise the degree of infolding present on the periphery of teeth decreases more apically and thus with age a more peripheral rim of enamel without deep enamel infolding can be present in mandibular cheek teeth that also become hollowed out.

\textbf{Dentine}

Dentine is the main component of the tooth and this mesenchymal tissue is continually secreted for the life of the tooth by odontoblasts that reside on the periphery of the pulp. Prior to dental eruption odontoblasts lay down what is termed \textit{primary dentine} which is the (very regularly oriented) outermost layer of dentine that is attached to the peripheral enamel at the amelo-dental junction. Later during dental eruption in the horse these odontoblasts lay down \textit{regular secondary dentine} that is of similar appearance to the primary dentine in that the dental tubules are straight. However, secondary dentine is more porous than primary dentine and absorbs food pigments – becoming darker (e.g. the “dental stars” in incisors) than the adjacent primary dentine. The next phase of dentinal deposition even in normal teeth that have not been exposed to a noxious stimulus, is the deposition in the more central areas of the pulp of \textit{irregular secondary dentine} which as its name implies has dental tubules oriented irregularly in various directions.\textsuperscript{5} In older horses this irregular secondary dentine will fully replace the subocclusal pulp. Over a 20 year lifespan of an equine cheek tooth, secondary dentine will gradually encroach on the 2 mm wide pulp horn laying down 1 mm of secondary dentine on each side until the pulp horn is fully obliterated, whereas at the same time in a tall cheek tooth, up to 100 mm of secondary dentine may need to be laid down subocclusally in order to prevent exposure of the pulps caused by dental attrition (normal dental wear).\textsuperscript{6} This finding indicates that there is a specific stimulation for secondary dentine deposition in the subocclusal pulp originating from the occlusal aspects of the teeth.

If pulps are exposed to a noxious stimulus, a further type of dentine termed \textit{tertiary dentine} can be deposited. There are two types of tertiary dentine, including \textit{reparative tertiary dentine} that is laid down if odontoblasts survive the pulpar injury, for example following dental fracture or pulpar exposure. In the absence of any viable odontoblasts following a pulpar insult, connective tissue cells (also of mesenchymal origin) within the pulp can change into odontoblast-like cells and lay down what is termed \textit{reactionary tertiary dentine} to seal off the underlying pulp from the oral environment or other noxious stimulus.\textsuperscript{7} Because of the intimate relationship of dentine and pulp they are sometimes termed the dentino-pulp complex.

\textit{Peripheral Cement(um)}

Cement is a cream coloured calcified tissue, with similarities to bone. In brachydont teeth cementum lies only subgingivally and its function is to anchor periodontal ligaments and thus
secure the tooth to the alveolar bone. A more detailed discussion of the periodontal ligament is presented in these proceedings by Dr. Staszyk. The prolonged eruption of equine teeth causes the cementum to continually ascend onto the clinical crown where it covers the enamel surface of the tooth with a variable thickness. Cementum thickness is greatest in the mandibular cheek teeth where the deep peripheral enamel infoldings are filled with and surrounded by thick cementum. Unlike brachydont teeth, cementum forms a major structural component of equine cheek teeth, giving it mechanical strength and wear resistance. Mitchell et al have also shown that the thickness of equine cementum - which is physically restricted when the tooth lies within the bony alveolus - increases immediately after the tooth erupts from the limitations of the alveolus. They have also shown that this recently erupted cementum on the clinical crown is viable, with blood vessels running some millimetres from the periodontal ligaments to this recently deposited, thick cementum. This cementum also contains viable cementoblasts and cementocytes.

At the end of enamel development the apex of the tooth cannot be called a true root. However, after eruption, much cemental deposition occurs to form the true roots and this deposition continues over the life of the tooth, until it becomes loose or is fully worn away. Unlike brachydont teeth, the subgingival cementum covering the reserve (unerupted) crown of the equine tooth (coronal cementum) is constantly remodelled as the periodontal ligaments are continually reformed and gradually extract the tooth into the oral cavity as further described by Dr Staszyk in these proceedings. Once the cementum rises above its vascular supply (a few mm above the gingival margin) it now is essentially a dead tissue (just like enamel) with no ability to repair itself. This peripheral cementum can later develops cemental caries

Infundibular Cementum

The single infundibulum of the incisors and both infundibulae of the cheek teeth contain infundibular cementum. Defects in cemental filling are termed infundibular cemental hypoplasia and a high proportion of cheek teeth have their infundibulae incompletely filled with cementum. Inexplicably the 09 position has much more infundibular cemental hypoplasia than any other Triadan position. These infundibular cemental defects are so common in equine cheek teeth (especially the 09’s) that they could almost be termed a physiological feature. However, these cemental defects can later get filled with food and subsequently develop caries that can cause clinical disease. It was previously believed that the only blood supply to the infundibulum came from its occlusal aspect from the dental sac vasculature, but as noted it has recently been shown that blood vessels penetrate the apical aspect of the teeth. Consequently, infundibular cemental deposition could continue following eruption, but inexplicably does not in many (especially Triadan 09) cheek teeth.

Once the overlying tooth has erupted and the cap and underlying dental sac is lost, the blood supply to the occlusal aspect of the permanent 06, 07 and 08 is lost. Many cheek teeth have a fine central defect in their infundibular cement which was the site of this dental sac blood vessel. Many infundibulae are curved and have cemental defects that can be over 70 mm above the occlusal surface. With the limited opening of the equine oral cavity, it is difficult if not impossible to access these defective areas of the infundibulae from the occlusal aspect, using straight drills.
Dental Pulp

Little is known about the histology of equine pulp but it appears to be more cellular and metabolically active than the pulp of brachydont teeth. This is not surprising considering the continual eruption and occlusal wear of hypsodont teeth over the horse’s life and consequently, the continuous need to lay down subocclusal secondary dentine to prevent pulpar exposure. Because of the high metabolic activity of equine pulp over a prolonged period it has a generous blood supply - unlike mature brachydont teeth. Therefore with pulpar exposure such caused by a dental fracture, when the pulp is exposed to the oral environment, the subsequent inflammation and oedema that develops in the pulp does not necessarily compress its large vasculature and cause pulpar ischaemia and death, as often occurs in brachydont teeth. With survival of the pulp, tertiary dentine can seal off any areas of exposed pulp, and the tooth then can continue to be viable.

The gross anatomy of the pulp chambers of the equine teeth was described by Dacre (2005) who showed a single pulp horn to be present in the incisors, canines and 1st premolar (wolf tooth). In younger horses, the pulp horn of incisors is displaced labially by the infundibulum, whilst in mature teeth, the apical aspect of the pulps are compressed laterally. In general, each cheek teeth has five pulp horns except for the rostral cheek tooth (Triadan 06) and the caudal (Triadan 11) cheek tooth. The 06’s have an additional pulp which is termed the 6th pulp which lies on the rostral, triangular-shaped aspect of this tooth (Fig. 2). This 6th pulp horn is prone to pulpar exposure or thermal injury if the (fully unvalidated) procedure of bit seating is aggressively performed. The caudal mandibular cheek teeth (311, 411) also have an additional pulp termed the 7th pulp, and mature maxillary 11’s have two additional pulp horns (7th and 8th). Dacre et al developed a numbering system for these pulps; however, this pulp numbering system was soon superseded by that of du Toit who developed a simpler system with the 1st pulp always lying on the rostro-buccal aspect of the tooth and the 2nd pulp on the caudo-buccal aspect of the tooth. The 3rd pulp is on the rostro-lingual aspect of the tooth. (Fig. 3).

Figure 2. Transverse section of a mandibular cheek tooth showing the additional (6th) pulp horn on the left side.
Figure 3. Pulpar anatomy of cheek teeth du Toit et al 2009,\textsuperscript{10} showing maxillary teeth on top row and mandibular teeth on bottom row. The teeth on left are the 06s, the central teeth represent the 07s-10s and the 11s are represented on the right.

**Thickness of Subocclusal Secondary Dentine in Cheek Teeth**

Until recently, there was limited information concerning the thickness of the subocclusal secondary dentine that protects the underlying cheek teeth pulp from exposure to the oral cavity. In the 1940’s Becker, suggested that 1 cm of secondary dentine was present above all pulps but recent work has shown much variation in the thickness of subocclusal secondary dentine with values of 10.8 mm and 9 mm reported for mandibular and maxillary cheek teeth, respectively.\textsuperscript{12} It has also been shown that the thickness of secondary dentine slightly decreases with age indicating that over time, teeth wear slightly faster than dentine is deposited. In particular this work has shown some variation even within normal teeth from 2 mm to 33 mm in depth as well as much variation between different teeth.\textsuperscript{12} The practical significance of this finding is that great care must be made when mechanically floating equine teeth to ensure that the pulp is not exposed or thermally damaged by the heat from such equipment which is not water cooled (currently the near-norm for equine dental equipment).

With recognition of the significance of equine cheek teeth diastemata over the past decade, and the subsequent widespread use of diastema widening to treat this disorder, the relationships of the occlusal aspects of the pulp to the mesial and distal margins of the teeth has also become very significant, in order to ensure that the pulps are not directly exposed or thermally damaged at these sites during diastemata widening. Recent work by Bettiol and Dixon has shown much variation in the distance between the pulp and the mesial or distal tooth margin which varies from 1.3 to 10.8 mm.\textsuperscript{13} In particular, it has been shown that the pulp horns (and thus pulp) at the distal aspect of the tooth are much closer to the interproximal space than are the pulps at the
mesial aspect of the tooth. The practical significance of this is that during diastemata widening, just 2-3 mm of dentine should be removed from any tooth and most should be removed from the mesial aspect of the tooth most distal to the diastema. Depending on the direction of rotation of the diastema burr used, and which side of the mouth is being treated, this can take some considerable skill.

Pulp and Dentine in Overgrown Teeth

As noted, nearly 100 times more secondary dentine is laid subocclusally than on the walls of the pulp horns providing evidence that occlusal stimulation is the main driver for deposition of subocclusal secondary dentine. Therefore in the absence of any occlusal stimulus, for example in a tooth whose opposite number has been lost, or where there is much reduced occlusal contact, for example in a tooth opposite a fractured, dysplastic or worn tooth (that contains less than a normal amount of enamel) there will be no or reduced stimulus for laying down subocclusal secondary dentine. This theoretically should cause the subocclusal dentinal thickness to become thinner than normal. However, this is counterbalanced by the fact that reduced or no attrition (normal wear) is taking place on the surface of the poorly opposed or unopposed tooth.14

The combined effect of these two opposing factors is that in general, there is a net increase in thickness of subocclusal dentine in overgrown teeth. However, whilst most overgrown teeth have such increased thickness of subocclusal dentine, this can vary between horses and even between individual pulp horns in the same overgrown tooth. Some overgrown teeth may even have thinner than normal subocclusal dentine. A take-home message from this work is that if overgrown teeth are reduced to the level of the adjacent normal teeth, this may cause pulp exposure. Even if pulp exposure does not occur during this procedure, the grinding away of such a large amount of dentine with un-cooled dental equipment could cause thermal damage to the underlying pulp. If the occlusal aspect of the pulp is thermally injured, it can no longer lay down secondary dentine and when the existing secondary dentine overlying this pulp is eventually worn away by normal wear, pulpar exposure can then occur and may lead to pulpar infection and even loss of the tooth.14

The Occlusal Surface

Immediately after eruption, the occlusal aspect of the tooth is covered by the soft-tissue dental sac, and when this is soon worn away, it exposes a tooth that is completely surrounded by cementum even on the occlusal surface. This is the primary occlusal surface but after a very limited amount of mastication this occlusal cementum will be worn away revealing the permanent occlusal surface which is a sandwich of different calcified dental tissue with cementum lying peripherally to enamel and (primary) dentine lying most centrally. With further dental eruption and wear, the subocclusal aspect of the pulp horn (beneath the primary dentine) becomes filled with secondary dentine. As the tooth later wears away, secondary dentine is then exposed on the occlusal surface. Enamel is by far the hardest tissue in the body and the peripheral (and infundibular on the upper teeth) ridges of enamel wear slowest and thus protrude on the occlusal surface, with the softer cementum and dentine being worn more quickly. This layering of hard but brittle enamel between the softer but flexible dentine and cementum creates a biological “safety glass” that helps prevent enamel and thus dental fractures.
**Pellicle**

Within minutes of being brushed, the enamel surface of a human tooth will develop an organic covering consisting mainly of mucopolysaccharides and glycoproteins from saliva, and oral bacteria to form what is termed as a pellicle. All horse teeth have an organic pellicle.\(^{15}\) If this organic layer becomes thicker, containing many bacteria it can eventually be termed dental plaque and has been suggested in the horse that a cut off point of a thickness of \(<10\mu m\) should differentiate between pellicle and plaque.\(^{16}\) In the normal horse the ingestion and mastication of coarse forage, that is low in soluble carbohydrates for very prolonged periods acts as a natural toothbrush and therefore plaque is not present on normal equine teeth except in the interdental areas as recently shown by Cox et al 2011.\(^{17}\)

**Occlusal Physiology**

A high level of normal attrition (wear) occurs on the surface of equine cheek teeth because of the low calorific content of their largely cellulose diet A study in Britain showed that horses graze for about 13 hours a day in the summer when the grass is most nutritious to over 16.5 hours a day in the winter when the grass is less nutritious (M. Booth 1996 personal communications). However, in poor winter weather, horses may graze for up to circa 20 hours a day, may graze lower and thus get more abrasive silica on their teeth and even eat a more woody type diet, with all of these factors increasing the attrition on their teeth, (M. Booth 1996 personal communications). Whilst masticating hay, a horse has between 58-66 chews per minute, taking approximately 4200 chews for every kg of dry matter. When at grass, horses chew much faster (100-105 chews per minute). Thus it can be seen in addition to eating for example up to 20 hours per day horses can have over 6000 chewing motions per hour on their teeth, all leading to the high rate of dental attrition of their teeth.

**Gross Anatomy of the Equine Teeth**

**Nomenclature**

In many brachydont species, the teeth form a full arch i.e. a continuous row of teeth from a caudal molar to the caudal molar on the opposite side of the mouth. The terms arcade and arch are thus suitable for this type of dentition. However, in the author’s opinion, with the horse where there is a straight row of six cheek teeth on each side that is separated by the physiological diastema (“bars of the mouth”) from the canine tooth (if present) and incisors, the term cheek teeth row is more appropriate. For the same reason terming the more rostral aspect of the cheek teeth row as medial (mesial) and the more caudal aspect as distal does not make anatomical sense in the horse, and the more anatomically accurate terminology are rostral and caudal. The equine incisors do form a true arch and the terms distal and mesial are applicable for these teeth.

**Incisor Development**

To describe the deciduous teeth using the Triadan system, an additional 4 is added to the first number. Using this system the deciduous 01’s (first incisors) are 501,601, 701, and 801; the deciduous 02s are 502, 602,702, and 802 and the deciduous 03’s are 503,603, 703, and 803. The
deciduous 01s erupt during the first week of life, the 02s at 4-6 weeks and the 03s at 6-9 months of age. The deciduous incisors are whiter and have wider and shallower infundibulae than the permanent teeth that normally erupt on their lingual aspect. They also erupt deep below the true roots of the deciduous teeth and cause their physiological resorption, as well as physically loosening them.

Ageing by Dentition

The eruption of the deciduous and permanent incisors can be used to relatively accurately age horses up 5 or 6 years of age. Beyond that time, the features which have traditionally been used for ageing such as the presence of occlusal secondary dentine (“dental stars”) and the disappearance of the infundibulae have now been scientifically shown to be unreliable. Many horses have very thin subocclusal secondary dentine and thus secondary dentine appears on the occlusal surface much earlier than traditionally believed. Some horses have much deeper infundibulum than what has been regarded as “standard” and thus their incisor infundibulae lasts for much longer than commonly accepted. Likewise the appearance of the “7 year hook” and “Galvayne’s groove” are unreliable indicators of age in some horses. For these reasons the ageing of horses by the morphological appearance of their incisors or cheek teeth after 6 years of age is inaccurate in many horses. If such ageing is attempted, its limitations must be fully acknowledged.

Canine Teeth

Deciduous canine teeth can occur in horses but they are vestigial, often only detected radiographically and they usually do not fully erupt. In female horses the canine teeth usually do not develop and if they do, they are vestigial in size and shape. The canine tooth usually fully develops only in male horses, usually erupting between 4-6 years of age although occasionally (including in miniatures) they may not erupt for a further year or so. Unlike all other classes of equine teeth, the canines are not in direct opposition with each other; the mandibular canine being more rostrally positioned than the maxillary canine. Although they have relatively small clinical crowns (1-2 cm in height), they can have a very long reserve crown (up to 7 cm in length) lying in the alveolus. The canine teeth have vertical clinical crowns, but the reserve crown usually lies horizontally in a caudal direction. It is not absolutely clear whether canine teeth are brachydont or hypsodont and it may be that they are somewhere between these two categories. Whilst some eruption of the canine tooth may occur throughout the life of the horse, many older horses have very long reserve crowns of their canine teeth and clarification of the nature of canine teeth is required.

The canine teeth are convex on their lateral aspect and concave on their lingual (medial) aspect. In many horses the single pulp cavity of the canine may lie less than 1 cm below the tip (occlusal aspect) of the clinical crown. Some operators consider it fashionable to reduce the clinical crown of the canines, purportedly to prevent contact with the bit; injury to other horses when fighting and to even prevent damage to the hands of veterinarians when performing dental examinations. These are all very dubious reasons to grind down perfectly healthy structures. If the canine teeth are reduced too much their pulp will be exposed, a consequence being that if the horse cannot seal the exposed pulp with tertiary dentine, the teeth will likely develop apical infection, general
periodontal disease and may eventually become painful and loose. A very important point when reducing any type of equine teeth that dentine is totally avascular. If any hint of pink occurs during a dental reduction procedure this means that the pulp has already been exposed and that dried blood from the exposed pulp is now covering the adjacent dentine.

**First Premolar (Wolf Tooth) (Triadan 05s)**

The Triadan 05 teeth erupt at about 1 year of age and have a reported prevalence of 24% in females and 15% in males. However, in older horses, a much lower prevalence of wolf teeth is present that may be due to loss of wolf teeth when the deciduous 06 (cheek teeth) are being shed at about 2.5 years of age. The Triadan 05’s appear to be brachydont teeth, but like canine teeth, they have not been fully classified in the horse. The presence of wolf teeth in individual horses has traditionally been claimed to cause a range of illnesses, including blindness to every possible behavioural and biting problem! In European countries, many older horses that have been ridden to the highest competitive standards still have their wolf teeth, whereas in other countries, their presence is regarded as being incompatible with use of a bit.

If a wolf tooth is very large and protruding into the bars of the mouth; is displaced; and particularly if it is a mandibular wolf tooth, it may then cause biting problems. In such cases, their extraction is justified. This procedure will invariably cause some discomfort to the horse for a few days. For most other horses with normal sized and positioned wolf teeth, there is no objective evidence that their extraction is of any benefit to the horse. Objective research is needed in this area so that veterinarians who consider that wolf teeth do not need to be extracted in some horses are not treated as if they do not know the “basic rules” of dentistry.

**Cheek Teeth**

*Nomenclature*

The term cheek tooth is a useful term to describe premolars 2, 3 and 4 and the three molars. Traditionally these 6 teeth have often been termed “molars” and many equine dental instruments still have this association, i.e. “molar cutters” or “molar shears” but this is an inaccurate term.

*Development*

Shortly after birth the 12 temporary premolars (Triadans 6, 7 and 8’s) erupt (Fig. 4) and these teeth are similar in *cross section* to the underlying permanent cheek teeth which develop later. In the neonatal foal the 3 deciduous cheek teeth occupy the full length of the mandible and maxilla. With jaw lengthening, there is now room for the 4th cheek tooth (Triadan 09) to erupt at one year of age. By 2 years of age there is room for the 5th cheek tooth (Triadan 10) and by 3-4 years of age (when the skull is almost at its full size) there is room for the 6th cheek teeth (Triadan 11) to erupt.

Radiographically, the developing cheek tooth can initially be seen as a rounded radiolucent structure. It later develops calcification of the vertical enamel folds and later on increasingly becomes morphologically similar to the mature cheek tooth. As the permanent tooth grows it
causes both physiological resorption of the apex of any overlying tooth, and physical displacement of it into the oral cavity, where the thin deciduous tooth remnant is known as a “cap”. As noted earlier the permanent tooth is covered by a dental sac which nurtures the peripheral cementum and the infundibular cementum in the upper cheek tooth. As soon as the underlying “cap” is dislodged, the soft tissue of the dental sac is immediately worn away and no further nutrition to the occlusal aspect of the erupting tooth is possible. It has been stated that premature extraction of the upper caps removes the blood supply to the infundibulum and this is a cause of infundibular cemental defects in the upper cheek teeth. However, as the upper 09’s alone contain 50% of all severely hypoplastic infundibular and the 09’s have no deciduous precursors, this theory seems invalid for most cheek teeth.

Clinical Crown Shape and Orientation

The first and last cheek teeth are triangular in shape and the remaining cheek teeth are rectangular shaped in the mandible and square in the maxilla. They are normally tightly compressed together at their occlusal surface at the interdental (interproximal) sites. This occlusal compression is due to the rostral angulation of the 11’s and to a lesser extent the 10’s that push their clinical crowns in a rostral direction and due to the caudal angulation of the clinical crowns of the 06’s (is normally shorter than the other cheek teeth) which compresses the occlusal aspect of the cheek teeth caudally (Fig. 5).

Figure 4. Mandible of a neonatal foal showing the 3 deciduous cheek teeth in each row.

Figure 5. Orientation of the cheek teeth clinical and reserve crowns in a young horse.

This caudal angulation of the 06 clinical crown was an evolutionary development in the horse when they developed the physiological diastema, otherwise all the cheek teeth would be tilted forward by the rostral pressure of the clinical crowns of the 10’s and 11’s. It is believed that this evolutionary development occurred simultaneously with the elongation of the horse’s head that may have been to allow it to both graze and observe for predators. Some diagrams of cheek teeth longitudinal and transverse sections are shown in Figs. 6-8.
Figure 6. Longitudinal and transverse section of a maxillary cheek tooth. The apical aspect of tooth is to the top of image.

Upper cheek tooth

Figure 7. Longitudinal and transverse section of a mandibular cheek tooth. The occlusal aspect of tooth is to the top of image.
Occlusal Transverse Ridges

In addition to the previous noted irregularity of the occlusal surface due to the differential wear between the hard enamel and the two softer calcified tissues, the occlusal surface of horses have a series of transverse protuberances that have been termed **transverse ridges**. These can be more technically described as styles or ridges which are linear elevations on the surface (occlusal or peripheral of a tooth). On the occlusal surface they can be due to the presence of interconnected cusps (elevations of the occlusal surface). Horses usually have between 11 and 13 transverse ridges that can vary in size between individuals, breeds and with age. These ridges are sometimes very pronounced on the caudal cheek teeth of younger horses and may be up to 7-8 mm high in such cases. These ridges have evolved to increase the occlusal surface area to increase the efficiency of grazing and they are a **normal** feature of horses. Using pseudoscience, recently some lay people have somehow come to the conclusion that despite their 50 million years of evolution, these ridges are not beneficial to the horse and should be rasped off, in the belief that they will improve rostro-caudal mandibular movement, which they somehow believe is of great advantage to the horse. If all theses ridges are of similar size, even if very tall, they should be regarded as normal features which should not be reduced by veterinarians.

![Figure 8. Longitudinal sections of a young maxillary cheek tooth showing two pulp horns and a long infundibulum with cemental defects.](image)
Peripheral Ridges of Maxillary Cheek Teeth

Ridges also occur on the peripheral aspect (buccal) of the upper cheek teeth, usually consisting of two prominent vertical ridges and often a smaller, less prominent caudal ridge. The height and shape of these ridges along the buccal aspect of the tooth varies greatly between individual horses. Horses with very prominent and sharp ridges are prone to develop sharp overgrowths on the occlusal aspect of the ridges that in particular, can cause ulceration of the caudal buccal mucosa particularly opposite the Triadan 10s and 11s. Such sharp ridges can occur in horses that have never been fed concentrates (hard food) and the influence of genetics, domestication and diet on the development of buccal ulcers in such cases it is unclear.

Root Development

Because of their hypsodont nature, equine cheek teeth can be of great length (i.e. 10 - 11 cm in larger horses) and these teeth gradually erupt at a rate of 2-3 mm per year over the life of a horse. As noted, cementum is deposited on the apical aspect of the enamel, forming the true roots a year or so following eruption and these roots gradually increase in length over the life of the tooth. The upper cheek teeth have two well defined buccal roots, (rostral and caudal) and a less defined longitudinal palatal root that is difficult to discern on radiographs. The lower cheek teeth have two (rostral and caudal) roots except the Triadan 11s that have 3 roots.

Sites of Reserve Crowns

All the mandibular teeth are by definition embedded in the mandible with the 10s and 11’s lying deep to the masseter muscles. The upper 06’s and 07’s, and in some horses the rostral aspects of the 08’s, lie embedded in the maxillary bone with relationships to the nasal cavity on their medial aspect and the maxillary bone laterally. The alveoli of the upper 08s and 09s normally lie in the rostral maxillary sinus which is separated by a bony septum from the caudal maxillary sinus which normally contains the alveoli and reserve crowns of the maxillary 10’s and 11’s. In the younger horses the maxillary sinuses are almost filled with the above alveoli and reserve crowns but with age (and continued dental eruption) the apical aspect of the alveoli gradually retracts from immediately beneath the infra-orbital canal in the young horse to up to 5-6 cm below this level in the older horse. Consequently, the maxillary sinuses become much larger in volume with age. The rostral angulation of the clinical crowns of the Triadan 10’s and 11’s and the caudal angulation of the 06s decrease as the tooth is extruded and with age, these teeth become more vertical in position. The cheek teeth also drift rostrally with age as can be noted on radiographs of the older horse.20

Shape of Cheek Teeth Rows

Although the cheek teeth are described as being in rows, the maxillary row in particular is not straight, being convex on its buccal aspect. A practical significance of this being that to reduce overgrowths on the buccal aspect of the caudal two maxillary cheek teeth a reverse angled rasp must be used and similarly, an angled rasp must also be used on the 06’s in order to reduce overgrowths. Equine cheek teeth also taper inwards from their occlusal to the apical aspect and thus become shorter in a rostral to caudal direction with age. A consequence of this along with
the loss of angulation of the rostral and caudal cheek teeth is that abnormal space termed a diastema develops between the cheek teeth in the senile horse that is termed *senile diastemata*.

*Figure 9. Right lateral view of an equine skull showing very prominent vertical ridges on the maxillary cheek teeth, minimal transverse occlusal ridges and a relative prominent curve of Spee.*

**Curve of Spee**

Another variable feature of the equine occlusal surface is a varying upward slope of the caudal mandible/maxilla (containing the caudal 2-3 cheek teeth) that is termed the curve of Spee. This dorsal curvature can be marked in some horses and is said to be most prominent in horses with convex faces such as Arabian horses but it can also occur in larger draft horses even those with a Roman-nose i.e. a more concave appearance of the face. If marked, the dorsally-sloping lower 10s and 11s can be mistaken as overgrown teeth and an ill-informed operator could reduce these teeth and cause pulpar damage. The fact that these teeth are not overgrown can be judged by assessing the height of clinical crown between the 08’s, 09’s, 10’s and 11’s. No matter how much upward curvature there is on the jaw, if the same height of clinical crown is present on these caudal teeth as is present on the rostral teeth, this indicates that there is no overgrowth of the caudal teeth. Even if true overgrowths were present, dental shears should never be used because of the variable and possibly thin layer of occlusal secondary dentine present in some horses.

**Anisognathia**

The maxillary cheek teeth rows are further apart than the mandibular rows and this difference is a median of 23% in horses. In donkeys, du Toit has shown similar values but the disparity of the distances between the upper and lower cheek teeth rows is greater caudally than rostrally.

**Occlusal Angulation**

Until relatively recently it was believed that the occlusal surface of cheek teeth rows had an angle of 15%, sloping in a medial to lateral direction. The consequence of this belief was that clinicians would examine the rostral mandibular cheek teeth and then see higher angles in the more caudal mandibular cheek teeth and consequently (using motorised equipment) mistakenly reduce the angles of the caudal teeth to make them similar to those of the rostral teeth. More
recent work has shown normal mandibular cheek teeth to have angles of circa 15° in the 06’s that increase up to 32° in the 11’s.\textsuperscript{22} In contrast, the maxillary cheek teeth have a higher angulation more rostrally for example 19° in the 06’s that decreases to about 9° in the 11’s.\textsuperscript{22} Therefore it can be seen that it is totally inappropriate to change all cheek teeth angles to 15° or to try and equalise the angles at the front and back of the mandible and maxilla or try to make the maxillary and mandibular angles similar. The angles of the teeth are governed by developmental factors (Fig. 10) and later by the type of diet and length of time masticating and degree of lateral motion of the mandible during this mastication.\textsuperscript{23,24} Likewise with painful disorders the full biggest lateral excursion will not occur with the mandible and higher angles (>45°, i.e. shearmouth) will develop on or both sides of the jaw that are not masticating normally.

![Image of neonatal foal showing angulation of the recently erupted cheek teeth.](image)

**Fig 10.** Neonatal foal showing angulation of the recently erupted cheek teeth.

**References**

Equine Periodontal Anatomy

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Take Home Message

The equine periodontium possess remarkable regenerative properties.

Introduction

The periodontium is constituted of four components: the alveolar bone, the dental cementum, the periodontal ligament (PDL), and the gingiva. The PDL is a fibrous connective tissue interposed between the dental cementum and the alveolar bone.\textsuperscript{1,2} It provides fixation of the tooth and withstands masticatory forces at the same time.\textsuperscript{3} These functional requirements are met by a unique architecture of a collagen fiber bundle system in combination with an ample blood vascular system.\textsuperscript{4-6}

Due to the lifelong eruption of the equine tooth the equine PDL has to provide mechanisms for continuous tissue remodeling and tissue repair.

The aim of the present series of studies was thus to identify specific components and mechanisms of the equine PDL that are involved in tooth support, acceptance of forces, tissue remodeling and tissues repair.

Investigations were focused on:

- the collagen fiber apparatus, i.e. its spatial arrangement, its changes during the process of tooth eruption, and its mechanisms of remodeling,
- the blood vascular system and lymph vascular system, i.e. their organisation, and their interactions with the collagen fiber apparatus,
- the cells of the periodontal ligament, i.e. their ability for proliferation and differentiation.

Materials and Methods

In a series of studies the equine periodontium has been investigated using histological methods, immunohistochemical stainings, vascular casting techniques and cell biological methods.

Results

Tooth support is achieved by collagen fiber bundles aligned in multidirectional arrangements.\textsuperscript{6} Thus, intrusive movements of the tooth and the sideward motion during the equine laterolateral
chewing cycle cause tensile load only in distinct groups of fiber bundles. Eruption is assured by a well-coordinated remodeling of the periodontal fiber apparatus. Collagen degradation is initiated by matrixmetalloproteinase-1 and occurs only within certain single fiber bundles. In this way the function of tooth support is always maintained while the collagen apparatus is submitted to remodeling in order to become adapted to the dynamic morphological changes.

The **blood vascular system** is a well adapted arrangement consisting of an inner capillary layer (near the tooth) and an outer venous layer (near the alveolar bone). This system contains specific vascular structures, i.e. blind vessels and large ampullae, but no venous valves. These structural features provide the requirements for the distinct functions of the blood vascular system, like nutrition and shock absorbency. Furthermore, it is assumed that the vascular system facilitates an intra-extravasal shift of fluids in order to generate hydrostatic pressures necessary for tooth eruption.

Characteristic **fibro-vascular arrangements** apparently meet the biomechanical requirements of the PDL during the chewing cycle. In a so-called type-I arrangement, a sheath of fibers and cells protects the blood vessels from the deformations of the surrounding tissue. In a type-II arrangement, tractive forces in collagen fibers are transferred to compress adjacent blood vessels (by what is called a lateral compression mechanism); in a type-III arrangement wide venules are assumed to act as a hemodynamic cushion, and collagen fibers prevent the vessels from shifting. The distinct combination of the physical properties of the collagen fibers (i.e. elasticity) and the intravasal blood content (i.e. viscosity) forms a visco-elastic system.

Initial **lymphatic vessels** are present in the PDL and in the adjacent bony spongiosa of the jaws. Their distribution leads to the assumption of two alternative ways of lymphatic drainage: ventrally into the mandibular lymph nodes, and caudally into the retropharyngeal lymph nodes.

The **periodontal cells** play a pivotal role in regulation and orchestration of periodontal remodeling and repair. This is reflected by an exceptionally high rate of cell proliferation in the equine PDL compared to other species. Further, the equine PDL houses a population of defined multipotent mesenchymal stromal cells which are capable of differentiation into certain cell lineages.

**Discussion**

The most notable aspect of the equine PDL is the constant, essential process of **tissue remodeling**, which is necessary for the continuous eruption of teeth. It is also an indicator of the high capability for regeneration and repair of the periodontal tissues. By utilizing the PDL specific multipotent mesenchymal stromal cells new therapeutic concepts in equine dentistry and periodontology might be available in the future.

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Oral and Dental Examination

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Take Home Message

With proper patient restraint and specific equipment, a thorough dental examination can be performed with minimal stress and risk to the horse and examining veterinarian. A thorough oral and dental examination is the basis of dental diagnoses, which are prerequisite to dental treatments. A dental record system is important in documenting findings and monitoring case follow-up.

Introduction

Oral and dental diseases are common occurrences in the equine species as evidenced by the results of incidence studies of dental disease performed on abattoir specimens. Casual oral or dental examination is part of a complete physical examination but is not sufficient to detect most oral or dental problems. This has been demonstrated by the reported high incidence and the comparatively low clinical diagnosis of dental disease. Signs of dental disease are often not apparent to the owner until the disease is well advanced. Clinical signs of dental disease are often not specific and may be reflected in other body systems. Presenting complaint in the owner’s or trainer’s own words should be taken into consideration when examining the horse and properly addressed in planning treatment.

While a comprehensive history and physical examination of every patient seen when performing routine dental evaluations and occlusal adjustment/equilibration is a valuable service to clients, this is not practical nor performed in most cases. However, one must establish the presence of medical problems through client history and clinical signs that may impact safe delivery of dental care. Minimal dental examination must be thorough enough to detect pathology in an early stage of development to prevent the progression of a pathological process to the point where correction is difficult if not impossible. Minimal dental examination includes observing and feeling both hard and soft tissues of the mouth for pathology. The hard tissues consist of the teeth and osseous structures. Soft tissues consist of the lips, cheeks, tongue, palate, gingiva, oral mucosa, lymph nodes and salivary glands. The extent of the examination increases if the history and physical findings warrant further inspection. Documentation of variations and/or abnormalities is the standard of care. Use of a standard dental record form leads to good examination habits. Computerized dental records make information more available for retrieval and case follow-up.

Equipment
Equipment utilized to properly examine the equine oral cavity is minimal, but certain items are necessary. The technique for restraint and size of equipment will both vary for different ages and sizes of patients. Very large (1000 Kg+) draft breeds require more restraint with heavier constructed equipment than the typical (500 Kg) riding horse. On the other extreme, small (100 Kg) ponies and/or miniature breeds require downsized equipment. Oral examination of small horses is best accomplished by positioning the animal on an elevated platform where the oral cavity is visualized at a more comfortable height. Equipment includes but is not limited to a halter and lead, a metal framed dental halter or head stand, a mouth speculum and a good light source (such as a clip-on speculum light or head lamp) mirror, explorer and probe.

Supplemental equipment can also be helpful. Various types of cheek retractors allow better visualization in the buccal spaces. A long-handled, rigid shaft equine dental mirror (2-5cm diameter) is suggested for viewing interproximal spaces and occlusal surfaces of the cheek teeth. The strong rigid handle is easy to retract the soft tissues and visualize hard-to-reach areas. An endoscope with a 30 to 75 degree angled lens can be used to further examine these areas. Attaching a video or still digital camera to the scope allows for relaxed viewing which can be an excellent tool for client education.

Other useful tools include long dental picks, probes, explorers and right angle alligator forceps. These instruments are especially useful in older horses for evaluating pockets between and around teeth as well as open pulp horns and other defects in the occlusal surface.

The exam will also require a bucket, clean equipment, and diluted disinfectant (chlorhexidine) solution to rinse the mouth. A 400 cc dose syringe with a blunt tip works well to rinse the mouth before the oral examination and during dental procedures. High pressure water irrigation can be used to remove debris from deep periodontal pockets. Irrigation aids evaluation of pocket depth and tooth stability. Lastly, disposable examination gloves protect the hands and make cleanup more efficient.

**Oral Examination**

A typical examination starts by taking a brief medical history while screening the animal from a distance. This gives the veterinarian a general idea of the type, thriftiness, general use and overall physical condition of the horse. View and ask about the animal’s feed and water sources, noting the amount and type of feed being consumed. Inspection of the horse’s manure will gain an idea of how well feed is being processed and digested. Survey the head for shape, symmetry and obvious abnormalities. Inspect and palpate the submandibular lymph nodes, submandibular and parotid salivary glands, masseter and temporalis muscles, TMJ and the ventral border of the mandibles. Digitally palpate for irregularities or tender areas especially along the upper dental arcade. Part the lips, inspect the incisors and estimate age before proceeding with examination of the oral mucous membranes, intermandibular space, and tongue. Perform range of motion of the jaw and lateral excursion to molar contact (EMC) maneuvers while noting grinding sounds and vibration with these movements.18
The oral examination continues with the interdental space and adjacent structures. This area often reveals the performance horse’s biting history. Evaluate the lip commissures, bars of the lower jaw, tongue and palate. In male horses over 4 years of age evaluate the canine teeth. Young adult stallions and geldings between the ages of 4 and 6 years of age may have canine teeth in various stages of eruption. Eruption cysts or tenting of the mucosa with ulceration over these teeth can cause oral pain and biting problems. Keep in mind that long sharp canine teeth can be a danger to the examiner and care should be exercised to avoid injury. About 25% of all mares have one to four rudimentary canine teeth. In older horses dental plaque or tartar can often accumulate around the canines leading to gingivitis. This calculus can also cover and mask cavities, resorptive lesions and fractures involving the canine teeth.

The upper and lower interdental spaces are examined by firmly running a thumb over the mucosa. Feel for protuberances above or below the gum line and observe the horse’s response to pressure. Check the lower bars for sharpness, bony irregularities, mucosal ulcers or thickening of the tissues. Feel rostral to the lower first cheek teeth for the presence of first premolars. The upper edge of the diastema is palpated for bony abnormalities and the presence of the upper first premolars. These caniniform teeth referred to as ‘wolf teeth’ erupt between 6 and 18 months of age. If present, they are located anywhere along the edge of the maxillary and palatine bones from the palatal side of each upper PM 2 and up to 2 to 3 cms rostral to this location. Wolf teeth usually erupt through the oral mucosa but can migrate under the mucosa and remain as palpable bumps. Unerupted or impacted wolf teeth, referred to as ‘blind wolf teeth’, can cause oral discomfort and training problems in bitted horses. Wolf teeth come in a vast array of shapes and sizes, and the visible crown shape has no relation to the size or shape of the root.

The tongue should be examined for function and anatomical abnormalities. Tongues are frequently injured from harsh bits or neglected tongue ties. Observe and palpate the hard palate. The hand can be introduced into the interdental space and a thumb pressed on the hard palate to make the horse open its mouth. The oral soft tissues should be observed with special attention paid to the palate, tongue and buccal mucosa. Calluses or ulcerations in the mouth are most likely the result of chronic trauma from sharp teeth and are self limiting. Lampas, or physiologic thickening of the palatal mucosa just behind the upper incisors, is common in young horses that are erupting permanent dentition and are not of clinical concern.

The entire oral cavity can only be fully and safely examined with use of a full mouth speculum. To place the McPherson-type speculum in the mouth, the examiner stands to the left side of the horse. With the left hand holding the mouthpiece and the right hand holding the poll strap, the mouthpiece is introduced between the incisors in the same manner as a bit. Use the left thumb and forefinger to open the mouth and guide the mouthpiece into place between the incisors while applying steady tension to the halter strap from behind the horse’s poll. When the speculum is properly positioned, adjust the strap length until the speculum strap is snug. Adjust the mouthpiece from the front to square it with the incisors. Open the jaws of the speculum one notch at a time until the jaws are opened wide enough to accommodate a hand and forearm. If the horse resists having its mouth opened with the speculum in place, the temporomandibular joints and bony structures of the jaw should be carefully evaluated before excessive force is placed on the jaw. At this point the oral cavity is ready for visualization and palpation. A head support stand or metal frame dental halter can be used to elevate the head of a sedated horse to a comfortable height for visualization and palpation.
The teeth should be evaluated for conformation, position and number. In the normal horse, the mean occlusal angle of the mandibular cheek teeth ranged from 19 degrees at the Triadan 06 position to 30 degrees at the 11 position. The maxillary cheek teeth have similar angulations at the 06 position but the occlusal angle decreases as you move caudally in the mouth. Common premolar findings include hooks, ramps, erupting teeth or loose caps (deciduous tooth remnants) and cap slivers. In the center of the molar table, one may observe long teeth, a wave, cupped out or decayed infundibula, missing teeth, fractured teeth or misplaced crowns. In cases of occlusal malocclusions, the overlong tooth is usually the nonpathological tooth and the opposite occlusal tooth should be thoroughly examined for causes of over-attrition. The caudal oral cavity should be inspected for the presence of buccal ulcers, sharp enamel points or hooks, supernumerary or missing teeth, diastema and periodontal pockets or ramped dental arcades. Enamel points that normally form on the buccal and lingual enamel folds or cingula usually do not protrude beyond the level of occlusal surface of the cheek teeth. Regular transverse ridging of the occlusal surface is normal and are associated with taller areas of increased enamel located between enamel outfoldings or cingula where the enamel points form. These should be differentiated from abnormal isolated or irregular transverse ridges that are wedge shaped elongations usually located opposite diastema or malaligned teeth. The acute angle between the vertical edge of the tooth and the occlusal surface can cause sharp enamel points to look and feel quite prominent. Inspect the mesial and distal dental margins for abnormal tooth contact, abnormally interproximal space width (diastema), and feed packed into gingival pockets. Most abnormal wear patterns are associated with some type of malocclusion. Recent use of the term class I malocclusion to describe common abnormal wear patterns seems justified and can help with planning corrective odontoplasty procedures.

Palpate the buccal, occlusal and lingual surfaces of all four arcades. The gingival margins of the cheek teeth should be uniform with no feed packing. The crown height should be the same on the mesial and distal aspect of each tooth. The crown height should be longer on the buccal aspect of the uppers and the lingual aspect of the lowers. This represents the normal slope of the molar arcade. Note any deviation or asymmetry in the molar table height or angle. Keep in mind that any defect in one arcade will usually be reflected in a wear abnormality or defect in the opposite occlusal arcade. Grasp each exposed tooth crown between the thumb and forefinger and check for stability. Digitally unstable teeth should be evaluated with the aid of an extraction forceps and assigned a mobility index.

A periodontal examination should be a standard component of the complete oral examination. Periodontal disease may be a manifestation of a variety of infectious and metabolic disorders, and it is not limited to dental pathology. Periodontal disease is painful. In some specific cases, patient anxiety levels may escalate on instrumentation of the oral cavity. Deeper sedation and local infiltration or regional anesthesia may be necessary under these circumstances. The gingival sulcus is checked for depth with a periodontal probe and examined for the tendency to bleed. If present, food material must be removed from periodontal pockets with dental picks, irrigation, and/or long-handed alligator forceps before pockets can be evaluated for pocket type (suprabony or infrabony) and pocket depth. Periodontal pockets are measured for depth, mesial to distal length, and width. Supra and subgingival surfaces of the teeth are evaluated for cemental abnormalities using dental explorers and mirrors: evidence of decay, calculus, fractures, and hypo or hyperplasia may be seen. If evidence of periodontal disease is found during the oral
examination, radiographic evaluation is indicated. A more detailed description for assessing the periodontium can be found in the literature.21

Evaluation of cavities or defects in the surface of teeth from any cause is one component in a complete dental examination. A cavity is usually detected during dental examination by visualization with a mirror or endoscope and tactile exploration of the teeth. Any suspicious areas of the crown should be explored with a dental explorer. The point of the explorer is pulled across the surface of the tooth. On normal dental tissue, the explorer will slide across the tissue surface and make a ringing sound. When pulled across diseased dental tissue, the explorer will drag across or stick into the surface of the tooth and make a dull sound. When pressed into diseased dental tissue, the explorer must be forcefully withdrawn. As the lesion progresses, the diseased tissue will show a brown discoloration, which must be differentiated from normally stained cementum or dentin. Further progression of the lesion usually produces surface cavitation filled with plaque, calculus (tartar), exudates, or necrotic black debris. Calculus should be scaled from the clinical crown of the tooth (especially canine teeth) to facilitate examination. After a lesion has been identified during the oral examination, it should be classified using standard AVDC approved system.22

Ancillary Diagnostic Tests

If the initial dental examination reveals signs of dental disease, further diagnostic techniques should be employed to make a more definitive diagnosis. A sedated and restrained or anesthetized horse will allow a more thorough examination. Endoscopy of the nasal passages, larynx and oral cavity is often indicated.23,24 Skull radiographs, both plain and contrast studies, give added information regarding dental, osseous and sinus structures. Standing skull films with the mouth propped open, provide a more complete assessment of the occlusal pattern of the dental arcade. Intraoral films provide the best detail of the reserve crown and marginal bone.25 Other imaging modalities such as ultrasonography, computerized tomography, nuclear scintigraphy or fluoroscopy may reveal a more accurate picture of certain dental pathology.26

Dental Records, Charting, and Treatment Planning

Charting is the process of recording the state of health or disease of the teeth and the oral cavity. To properly chart the mouth, the dental formula and anatomical locations in the mouth must be standardized to make documentation consistent. Use of standard abbreviations for dental terms to describe anatomical boundaries, pathology, diagnostics and therapeutic procedures have made communication possible between colleagues in both the veterinary and human dental professions.27 The American Veterinary Dental College Nomenclature and Classification Committee have endorsed the use of the Triadan tooth numbering system.
Note in the dental record: the horse’s signalment, use, management, presenting complaint and any pertinent history with special emphasis on the digestive system and any performance problems. Assign a numbered body score indicating the horse’s general condition. Formulate a treatment plan for each problem based on the history, clinical findings and oral examination before proceeding with any dental work. This problem-orientated approach is important and informs the owner and/or trainer of abnormalities, the treatment plan and a cost estimate of any corrective procedures. An owner consent statement is often included in record forms and can minimize problems should a legal claim be filed against the veterinarian or a bill come into dispute for collection. An in-depth review of dental charting can be found in the 2010 AAEP proceedings.27

References and Suggested Reading Materials

How to Document a Dental Examination and Procedure Using a Dental Chart

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Introduction

A dental chart is a permanent record of a patient’s dental care, and completion of a dental chart is the minimum standard of care for documenting any professional dental procedure. Dental charting is the process of recording the state of health or disease of the teeth and oral cavity, and it is an integral part of the examination, diagnosis, treatment planning, and monitoring of dental cases.\(^1\) The dental chart provides legal documentation of the procedure performed, and facilitates communication with colleagues.

The scope of this paper is limited to documenting routine equine dental care (Occlusal Adjustment, Floating, Periodontal Therapy, and Simple Extractions). Although the purpose of this paper is not to describe how to perform a dental examination, a thorough oral examination is prerequisite to completing an accurate dental chart. Additionally, in order to properly document any dental procedure and to communicate with colleagues, practitioners must have a working knowledge of dental terminology.

Standardized Terminology and Abbreviations

To facilitate communication between colleagues, the Nomenclature Committee of the American Veterinary Dental College (AVDC) reviews, clarifies, and recommends standardized terminology for dental and oral anatomical locations, pathologies, diagnoses, treatments, procedures, and dental materials. Terminology and abbreviations specific to equine dentistry have also been accepted by the Academy of Veterinary Dentistry (AVD). An extensive glossary of veterinary dental terminology can be found in veterinary dental texts.\(^2,3\) Extensive lists of the abbreviations accepted by the AVDC and the AVD are available online within the application packets for these organizations. Diagnostic and treatment abbreviations commonly used by the author are listed in Appendix A.

Although various systems for describing and numbering teeth are recognized, the Modified Triadan Tooth Numbering System is the tooth identification system of choice in veterinary dentistry.\(^4\) This system is applicable to most domestic animal species and provides accurate tooth identification in both written and oral communication. Each tooth is assigned a unique three digit number. The first digit designates the tooth’s quadrant and dentition, and the second and third digits designate the specific tooth. Teeth in each quadrant are numbered sequentially from the first (central) incisor (X01) distally to the third molar (X11), assuming a complete phenotypic equine dentition \([ I 3/3 \ C 1/1 \ P 4/4 \ M 3/3] \times 2 = 44\].
101-111: Maxillary right quadrant, permanent dentition.
201-211: Maxillary left quadrant, permanent dentition.
301-311: Mandibular left quadrant, permanent dentition.
401-411: Mandibular right quadrant, permanent dentition.
501-508, 601-608, 701-708, 801-808: deciduous 100, 200, 300, 400 dentition, respectively.

The typical domestic male horse is missing his mandibular wolf teeth, and many domestic mares are additionally missing all canine teeth; therefore, the dental formulae for male and female equids are [(I 3/3 C 1/1 P 4/3 M 3/3) x 2 = 42] and [(I 3/3 C 0/0 P 4/4 M 3/3) x 2 = 38], respectively. In the Modified Triadan System, “The Rule of Four and Nine” is used to simplify annotation among various species and variations within a species. Tooth X04 is always the canine tooth (104, 204, 304, 404), and tooth X09 is always the first molar (109, 209, 309, 409). Applying this rule, the first molarized cheek tooth (the 2nd premolar) in domestic horses is tooth X06 (106, 206, 306, 406).

**The Dental Chart**

The dental chart is a record of the condition of the patient’s dentition and oral cavity. It should include a dental history, oral examination findings, proposed and completed dental procedures, proposed future dental care, and home care instructions. Although many small animal and human dentists prefer a two chart system (one chart for recording examination findings, diagnoses, and proposed treatment planning and a second chart for recording the treatment performed), most equine dental practitioners use a combined report for both the examination and treatments. The most commonly accepted chart format is an anatomical dental diagram supplemented by brief descriptions to clarify the examination findings, diagnoses, and procedure performed. Most dental charts are designed with a fill-in-the-blank and check-off format to ensure consistent documentation. The dental chart should include a legend for nonstandardized symbols and abbreviations; however, the use of approved AVDC/AVD abbreviations should minimize this requirement. To meet the legal requirements of medical documentation, most state veterinary practice acts require that the following information be included in the medical record:

1. Date
2. Primary Complaint
3. History
4. Physical Examination Findings
5. Preliminary Diagnosis with Rule Outs
6. Tests performed and results
7. Diagnosis
8. Treatment Plan, implementation, drugs administered, and procedures performed
9. Prognosis
10. Patient Progress
Materials and Methods

The following outline describes the steps in documenting a dental procedure using the author’s combined format (examination and treatment) equine dental chart (Appendix C):

1. Documentation of all veterinary cases begins with recording the owner information, patient’s signalment, and primary complaint for the visit.
2. The patient’s history is taken with particular emphasis on the horse’s use, bit & bridle, diet, and masticatory & performance problems.
3. A thorough physical examination is performed and documented. The clinician must first rule out sources of systemic disease before any elective dental procedures is performed. Since sedative restraint is required for a thorough dental examination, emphasis during the physical examination should be placed on the horse’s body condition and cardiovascular system.
4. Once diseases of other body systems are ruled out, the horse’s head is examined and abnormalities recorded.
5. Upon completion of the external examination, the horse is sedated for oral examination. Sedative and other medications are recorded on the dental chart as they are given during the procedure.
6. Oral examination includes the examination of all tissues in the mouth. The soft tissue findings are documented in the appropriate fill-in-the-blank section of the chart. (e.g. “a cheek laceration caused by a hard enamel point on the maxillary right 1st molar” is abbreviated “LAC/B 110.”
7. Dental abnormalities are documented on the dental diagram and explained in the Exam Findings section of the chart using the appropriate diagnostic abbreviation followed by the affected tooth’s Triadan number, and the aspect of the tooth when appropriate. The tooth aspects are Apical, Coronal, Occlusal, Mesial (M), Distal (D), Palatal (P), Lingual (L), and Vestibular (V). Rostral and caudal refer to positional and directional terms relative to the head in a sagittal plane. A “forward slash” (/) or a “space” is often used between abbreviations for clarity. For example, “a hook on the maxillary right 1st cheek tooth” is abbreviated “HK 106.”
   a. Clinically missing teeth are “circled” on the diagram and annotated by the tooth number and the abbreviation “O”. (e.g., An absent maxillary left 2nd incisor is abbreviated “O/202”). During the mixed dentition period, unerupted molars are recorded by “circling” the adult molar on the dental diagram.
   b. The presence of deciduous dentition is annotated on the dental diagram by placing a single line through the adult tooth number and writing in the appropriate deciduous tooth number. (e.g. 408 508)
   c. Supernumerary Teeth and Retained Deciduous Teeth are drawn on the diagram and appropriately annotated. (e.g. SN 111, not 112 and RD 503)
   d. An unerupted or a partially erupted tooth is usually “impacted;” therefore, “a blind maxillary right wolf tooth” is abbreviated “TI 105.”
   e. Dental malocclusions, fractures, cavities, and periodontal pockets are drawn on the chart to approximate the outline of actual finding and annotated in the Exam Findings section.
8. Malocclusions and other abnormal dental findings commonly effecting the Incisors include:
a. Diagonal Bites are defined with respect to the mandibular incisors. DGL/3 is a diagonal bite in which the mandibular left incisors are longer than the mandibular right incisors. (Fig. 1) DGL/4 is a diagonal bite in which mandibular right incisors are longer.

b. Figure 1. Dental diagram charting a Diagonal Bite 4 (DGL/4).

c. Ventral Curvature (CV) and Dorsal Curvature Bites (CD) are the dental terms for a smile and frown bite, respectively.

d. Although Overbites and Underbites usually affect the entire dentition of a patient, these malocclusions are typically recorded in the Incisor part of the Exam Findings section as MAL2 or MAL3, respectively.

e. Hooks on the maxillary 3rd incisors are a common finding. (HK 103/203) (Fig. 2)

f. Abnormal wear patterns or “attrition” such as that seen in cribbers is recorded by describing the effected aspect of the tooth. (e.g. “cribbing attrition on the vestibular aspect of the maxillary 1st incisors” is abbreviated “AT 101V/201V”)

g. Crown fractures of the incisors should be drawn on the dental chart and described. (e.g. “a crown fracture of the maxillary right 3rd incisor” is abbreviated “T/FX 403CR”). The extent of the fracture can be further described using the tooth fracture abbreviations (“T/FX/”) in Appendix A.

h. Iatrogenic pulp damage secondary to over-reduction of the incisors with power instrumentation is a common finding. Exposed pulp is differentiated based upon its vitality and recorded. (e.g. “a living, bleeding pulp in the mandibular right 3rd
incisor” is abbreviated “T/PE/V 203;” whereas a necrotic, nonvital pulp in the same tooth is abbreviated “T/PE/NV 203.”

i. Cavities (abbreviated CA) should be staged according to severity:
   i. Stage 1: Cavities in the cementum only. (CA1)
   ii. Stage 2: Cavities through the cementum and into the enamel. (CA2)
   iii. Stage 3: Cavities involving the cementum, enamel, and dentin. (CA3)
   iv. Stage 4: Cavities exposing pulp. (CA4)

j. Tooth resorption (Equine Odontoclastic Tooth Resorption and Hypercementosis [EOTRH]) should be classified using the AVDC classification (See TR in Appendix A)

9. Dental findings commonly affecting the canine teeth include:
   a. Tartar (calculus, abbreviated CAL) that may be associated with periodontal disease (discussed below).
   b. Blind canines in young males and mares (TI).
   c. Vestigial canines commonly seen in mares. No dental abbreviation is recognized for this finding; therefore, he uses a check-the-box format in the Exam Findings section of the dental chart to record this finding.
   d. Cavities and tooth resorption is annotated as described for incisors.

10. Dental findings commonly involving the wolf teeth include missing (0) and blind teeth (TI).

11. Dental malocclusions and findings commonly affecting the cheek teeth include Hooks (HK), Ramps (RMP), Waves (WV), Steps (STP), Abnormal Transverse Ridges (ATR), Hard Enamel Points (PTS), Cupped Teeth (CUPD), and Expired Teeth (EXP). These findings are documented on the dental diagram by drawing the lateral profile of the cheek tooth arcade onto the diagram. The individual tooth malocclusions are clarified in the Exam Findings section of the dental chart (Fig. 3).

   ![Figure 3. Dental diagram charting a typical cheek tooth malocclusion pattern (HK206/311, WV 308-9, ATR 210/311.]

   12. Dental abnormalities affecting the occlusal aspect of the cheek teeth, such as fractures and infundibular cavities are best documented on an occlusal diagram such as the Dacre Equine Endodontic Numbering System Chart (Appendix C). The lesion is drawn onto the chart and is described both in the occlusal chart margin and in the Exam Findings section of the dental chart.
   a. Occlusal fractures often fit into one of the following categories:
      i. Chip: Fracture involving only the occlusal margin. (T/FX/CHIP)
ii. Wedge: Fracture outside the infundibulae, involving one or more pulp horns. (T/FX/WDG)

iii. Sagittal: Fracture through the infundibulum. Classically, through both infundibulae. (T/FX/SAG) (Fig. 4)

iv. The AVDC has further divided tooth fractures into seven classifications. (See T/FX/ in Appendix A)

Figure 4. Dental diagram charting a sagittal fracture of tooth 109 with a missing (vestibular) buccal slab, a Grade 2 Infundibular Cavity in the mesial infundibulum of tooth 110, and cupping in tooth 111 (FX/SAG 109, 0 109/V, INF/CA2 110, CUPD 111).

b. Infundibular cavities (abbreviated INF/CA) should be staged according to severity:
   i. Stage 1: Cavities in the infundibular cementum only. (INF/CA1)
   ii. Stage 2: Cavities involving the infundibular cementum and infundibular enamel ring. (INF/CA2)
   iii. Stage 3: Cavities involving the infundibular cementum, enamel, and dentin. (INF/CA3)
   iv. Stage 4: Cavities through the infundibulae resulting in tooth fracture. (INF/CA4) This staging is rarely used since the pathology is usually documented as a sagittal fracture. (T/FX/SAG)

13. Periodontal disease should be noted on the dental diagram and described in the Examination Findings.
   a. Periodontal pockets should be probed and their depths recorded. (e.g. “a 15mm deep periodontal pocket on the distopalatal interproximal aspect of the maxillary left 4th premolar” is abbreviated “PP15 208IPD/P” (Fig. 5).
Figure 5. Dental diagram charting a diastema and periodontal pocketing between the maxillary left 3rd and 4th cheek teeth (DIA/PP15 208IPD).

b. Teeth affected by periodontal disease should be checked for Mobility and the Index recorded:
   M1: less than 1mm movement in any direction.
   M2: less than 2mm movement in any direction.
   M3: movement of 3mm or more in any direction.

c. After radiographic evaluation, the Periodontal Index Stage can be determined:
   PD1: Gingivitis only, no bony attachment loss.
   PD2: less than 25% attachment loss.
   PD3: 25-50% attachment loss.
   PD4: greater than 50% attachment loss.

14. Many dental and oral pathologies can only be diagnosed with radiography. Radiographic findings should be recorded on the dental chart (preferably) or on a separate radiology report.

15. Once a complete oral examination and ancillary diagnostics have been completed, a tentative treatment plan and fee estimate is formulated. Upon approval, treatment procedures are performed and annotated on the dental chart (Figs. 6, 7, and 8).
   a. Occlusal Adjustment reductions are recorded on the dental diagram by “shading in” the portion of each tooth that has been removed and describing the procedure in the Treatment section of the chart. The appropriate dental term for the adjustment of the contour of a tooth crown is odontoplasty (OD).
   b. Floating (FLT), the reduction of sharp enamel points (PTS), is recorded in the Treatment section, but is not usually drawn on the dental diagram.

Figure 6. Dental diagram charting the correction of the DGL/4 presented in Fig. 1 (I/OD).
c. Simple extractions of retained deciduous and wolf teeth are common procedures and are recorded by drawing an “X” through the extracted tooth on the dental diagram and annotating the procedure in the Treatment section. (e.g. “Simple extraction of the maxillary right wolf tooth” is abbreviated “X105,” and “simple extraction of the mandibular left 2\textsuperscript{nd} cheek tooth cap” is abbreviated “X707.”) (Fig. 9)

d. Many commonly used nerve blocks have recognized abbreviations. Practitioners who perform infiltration nerve blocks before extracting wolf teeth can abbreviate the procedure as “BUC/LIP/X 105/205” to indicate that a “Buccal Local Infiltration Anesthesia, Local Infiltration Anesthesia of the Palate, and Simple Extraction of both maxillary wolf teeth” were performed.

e. Periodontal treatments should be recorded in the Treatment section of the chart.
   i. Supragingival Calculus Scaling, Closed Root Planning ( RPC) and Subgingival Curettage ( SC) are procedures applicable to equine incisors and canine teeth. No standardized abbreviation for supragingival calculus scaling exists (because dental professionals assume this procedure will be performed); therefore, the author has a check-the-block format in the treatment section to record this procedure.
   ii. Although the bradydontic periodontal treatment terminology (e.g. RPC, SC) is often used to describe periodontal pocket debridement involving equine cheek teeth, clinicians must understand that current instrumentation limits our ability to perform these procedures correctly, and the use of these terms may be inappropriate. The author elects to describe the actual treatment performed.
   iii. The application of perioceutic medicament (PCT), such as Doxyrobe, and bone grafting materials (BG), such as Consil, should be annotated in the treatment section of the dental chart.
f. Endodontic, orthodontic, oral surgery and restorative procedures can be documented on a dental chart; however, individualized case reports may be more appropriate for advanced dental procedures with preoperative diagnostic work-ups, prolonged sedative/anesthetic protocols, repeated intraoperative radiography, ancillary treatments, and extended aftercare requirements.

16. The visit is completed by prescribing necessary medications and aftercare, recording any special instructions, and scheduling the next examination, treatment, or follow-up procedure.

Results

Documentation of a dental examination and dental procedures using a dental chart:
1. Facilitates providing consistent quality dental care to patients by developing good examination habits.
2. Facilitates accurate treatment planning and fee estimation.
3. Accurately reflects the patients past and present care, as well as establishes a future treatment plan.
4. Provides legal documentation of the procedure performed.
5. Facilitates communication with colleagues.

Discussion

Until recently the horse industry and some equine practitioners have considered equine dental procedures to be nonprofessional services; therefore, the documentation of dental services has been inconsistent and nonstandardized. The recognition of dentistry as a professional veterinary discipline dictates that practitioners document these services and the Dental Chart provides equine practitioners with a concise, legally recognized format for reporting these services. During the initial period when a practitioner is learning how to use the dental chart, terminology, and abbreviations, charting can be cumbersome; however, once dental charting becomes a routine event, a case can be documented in a few minutes.

The dental chart can be either hand written or computerized, but accompanying digital photography always helps to clarify the recorded document. Several dental supply companies and printers sell equine dental charts, or a practitioner can personalize a dental chart to his/her practice, and some practitioners prefer to use a duplicate chart format so that the client receives a copy at the completion of the dental procedure. While practitioners can debate about which chart format and which abbreviations are “the best,” as long as information is completely documented in a legible manner that other colleagues can understand, the format of the report is a matter of personal preference. Whichever format a clinician chooses, dental charting will always improve the quality of care that the practitioner provides to the equine patient.

Sample dental charts are available online at www.aaep.org.

References and Footnotes


Suggested Reading:

Appendices:
Appendix A: AVD Equine Dental Abbreviations Supplement.
Appendix B: The Dacre Equine Endodontic Numbering System.
Appendix C: A Completed Dental Chart.
Appendix A: Equine Dental Abbreviations

Diagnostic Abbreviations
Abbreviations in RED are recognized by the American Veterinary Dental College (AVDC). Abbreviations in BLUE are recognized by the Academy of Veterinary Dentistry (AVD).

Tooth Aspects
- **V** Vestibular (AVDC Preferred)
- **B** Buccal
- **L** Lingual
- **P** Palatal
- **IPM or D** Interproximal: Between teeth. Mesial or distal.

**AB** Abrasion (Tooth or soft tissue). Pathological wear.
**AT** Attrition. Physiologic wear.
**ATR** Abnormal Transverse Ridge.
**CA** Caries
  - **INF/CA** Infundibular Cavity
**CAL** Calculus.
**CV** Ventral Curvature: Maxillary central incisors extend beyond the level of the maxillary intermediate and corner incisors, “smile”.
**CD** Dorsal Curvature: Mandibular central incisors extend beyond the level of the mandibular intermediate and corner incisors, “frown”.
**CUPD** Cupped: Crown worn past infundibulum. Still has crown above gingival margin.
**CWD** Crowded Tooth.
**DGL** Diagonal: Mandibular incisors longer on either the left side or right side. Defined with respect to mandibular incisors longer on arcade number 300 or 400.
  - **DGL/4400** arcade longer
  - **DGL/3300** arcade longer
**DIA** Diastema between proximal incisor or proximal cheek teeth.
**E** Enamel.
  - **E/D** Enamel Defect.
**EXP** Expired: Attrition to gingival margin with crown connecting all roots.
**EXT** Extrusion.
**FB** Foreign Body.
**FX** Fracture. Tooth or Bone, Also see Tooth Fracture (T/FX).
**HK** Hook: Excess crown longer than wide.
**GH** Gingival Hyperplasia/Hypertrophy.
**GR** Gingival Recession.
**LAC** Laceration.
  - **LAC/B** Laceration Cheek (Buccal)
  - **LAC/L** Laceration Lip.
  - **LAC/T** Laceration Tongue.
**M** Mobile Tooth.
  - **M1** Mobile Tooth Index Stage 1. First distinguishable sign of movement.
  - **M2** Mobile Tooth Index Satge 2. <3 mm of movement in any direction.
M3 Mobile Tooth Index Stage 3. >3 mm of movement in any direction.

MAL2 Class II malocclusion, overbite, brachygnathism, mandibular brachygnathism: Extension of maxillary teeth vertically beyond mandibular teeth. Defined by the term "distoclusion", where some or all of the mandibular teeth are distal in relationship to their maxillary counterparts.

MAL3 Class III malocclusion, underbite, prognathism, mandibular prognathism: Defined by the term "mesioclusion", where some or all of the mandibular teeth are mesial in their relationship to their maxillary counterparts.

MN Mandible.
MX Maxilla.
O Missing/Absent.
OAF Oroantral Fistula.
ONF Oronasal Fistula.
OM Oral Mass.
PDI Periodontal Disease Index
PD1 PD Stage 1: Gingivitis only.
PD2 PD Stage 1: < 25% attachment loss.
PD3 PD Stage 1: 25%- 50% attachment loss.
PD4 PD Stage 1: >50% attachment loss.
PE Pulp Exposure
PP Periodontal Pocket
PTS Sharp Enamel Points: Buccal cusps on maxillary cheek teeth and lingual cusps on mandibular cheek teeth sharpened from wear (attrition).
RAD Radiograph
RD Retained Deciduous Tooth
RMP Ramp: Excess tooth wider than long.
RRT Retained Root Tip: Portion of root or tip retained.
RTR Retained Tooth Root.
STP Step: One tooth only with excess crown.
T Tooth
T/A Avulsed Tooth.
T/FX Tooth Fracture
T/FX/EI Enamel Infraction.
T/FX/EF Enamel Fracture.
T/FX/UCF Uncomplicated Crown Fracture.
T/FX/CCF Complicated Crown Fracture.
T/FX/UCRF Uncomplicated Crown-Root Fracture.
T/FX/CCRF Complicated Crown-Root Fracture.
T/FX/RF Root Fracture.
T/FX/SAG Sagittal: Below gum line (subgingival) through infundibulum.
T/FX/WDG Wedge: Outside infundibulum.
T/FX/CHIP Chip: Occlusal margin only. Not fractured down to gingiva.
T/I "Tooth impacted", "Blind": Not completely erupted. Partially or fully covered by bone or soft tissue. Commonly seen with wolf teeth.
T/NE Near Pulp Exposure
T/NV  Non-vital Tooth  
T/PE  Pulp Exposure  
T/V  Vital Tooth  
TR  Tooth Resorption  
TR1  TR Stage 1: Mild. Cementum +/- enamel.  
TR2  TR Stage 2: Moderate. Lesion extends into dentin, but not into pulp cavity.  
TR3  TR Stage 3: Deep. Lesion extends through dentin into pulp cavity.  
TR4  TR Stage 4: Extensive. Compromised integrity.  
   TR4a  Crown and Root Equally affected.  
   TR4b  Crown more severely affected than Root.  
   TR4c  Root more severely affected than Crown.  
TR5  Tooth remnants radiographically. Gingival covering complete.  
TO  Tooth Overlong.  
WV  Wave: More than one tooth with excess crown.  

**Treatment Abbreviations**

B  Biopsy  
   B/E  Biopsy Excisional.  
   B/I  Biopsy Incisional.  
BG  Bone Graft.  
DB  Dentin Bonding  
FLT  Float: Reduction of lingual and buccal enamel points.  
GV  Gingivectomy/ Gingivoplasty.  
OC  Orthodontic Consultation.  
OD  Odontoplasty: Reduction of excessive crown of occlusal surface.  
PCT  Perioceutic Therapy  
R  Restoration  
   R/C  Restoration with Composite  
   R/I  Restoration with Glass Ionomer.  
SC  Subgingival Curettage  
TP  Treatment Planning  
VP  Vital Pulpotomy  
X  Extraction, simple  
   XS  Extraction, Tooth sectioned  
   XSS  Surgical extraction  

**Nerve Blocks**

IFA  Inferior Alveolar NB (Mandibular Nerve).  
IFO  Infraorbital NB.  
MAX  Maxillary NB.  
MEN  Mental NB.  

BUC  Buccal Local Nerve Block  
LIP  Local Infiltration of Palate
Appendix B: The Dacre Equine Endodontic Numbering System
Appendix C: A Completed Dental Chart

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**EQUINE DENTAL CARE**
**ANIMAL CARE HOSPITAL, 8565 Hwy 64, Somerville, TN 38068, (901) 466-9224**

**Equine Dental Examination / Treatment Record**

- **Horse:** Windy
- **Owner:** Sue Day
- **Barn:** Sunnyme Hill
- **Trainer:**
- **Date:** 3-15-07
- **Breed:** Arab
- **Age:** 12
- **Sex:** F
- **Color / Markings:** Chestnut
- **RDVM:** CE
- **Use:** Pleasure, Breeding, Retired, Performance, Other:
- **Complaint:** Routine Dental Care, Dental Recheck
- **History:** Last Dental Work (Date / Dentist): Classic Equestrian Vet 12-12-05
- **Wt. Loss:** O DROPPING FEED
- **Abnormal Chewing:** O QUIDDING
- **Performance Problems:** O Head Tossing, O Head Tilt, O Resisting
- **Physical Examination:** O Digital Pictures, O Radiographs: UIJ, C 100's 200's 300's 400's
- **Condition:** BCS 5 of 9 O Underweight, O Normal, O Overweight, O Obese
- **Feces:** O Not Examined, O Normal, O Large Stems
- **Poll Sensitivity:** O Normal, O Mild, O Moderate, O Severe
- **Odor:** O Normal, O Oral, O Nasal
- **TMJ Sensitivity:** O Normal, O Mild, O Moderate, O Severe
- **Dissymmetry:** L / R Larger
- **Cheeks:** O Normal, O Buccal Laceration / Ulcer
- **Lips:** O Normal, O Abnormal:
- **Gums:** O Normal, O Periodontal Pockets / Diastemata:
- **Other Findings / Rads:**

---

**Sedation:**

- **Sedivet (10mg/ml):** 1.5 cc / 14422
- **Dormorsetan (10mg/ml):** 0.3 cc / 14447
- **Torbugest (10mg/ml):** 0.3 cc / 14447
- **Diazepam (5mg/ml):** ce / ce

**Reversal Agents:**

- **Yohimbine (5mg/ml):** ce
- **Atipamezole (5mg/ml):** ce

**Local Anesthetic:** Lidocaine 2%

---

**Examination & Treatments:**

- **% Molar Occlusion:** Right: Before: A: <50 After: ≥50 Right: A: ≥50
- **Molar Table Angles:** Right: B: 0-10 Degrees Left: A: 10-15 Degrees
- **Occlusal Equilibration and Hard Enamel Points Floated:** 300's
- **Cusps:** 400's
- **Teeth:**
  - **Incisors:** Under Jet 3mm
  - **Canines:** Farfar Long Sharp, Vestigial, Prev. Reduced
  - **Wolfs:**
    - **100 Molars:**
    - **200 Molars:**
    - **300 Molars:**
    - **400 Molars:**

---

**Prescriptions:**

- **TMP/SMZ 960mg:** Give ___ pills twice daily for ___ days.
- **CHX Soln 0.05% Oral Rinse BID for ___ days.

**Recommended Procedures:**

- **X-rays, Extractions, Other:**

**Special Instructions:**

- **Recheck / Next Dental Appointment:** 6 months, 3 months, 1 year
- **Other:**

---

Please Call if you have any questions or concerns!!!
Equine Dental Radiography

Robert M. Baratt, DVM, MS, FAVD

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Indications

The indications for dental radiography include, but are not limited to:

- Maxillofacial trauma
- Assessment and staging of periodontal disease
- Malocclusion assessment and orthodontic treatment planning
- Exodontia
- Abnormal tooth numbers
  - Persistent deciduous teeth
  - Supernumerary teeth
- Facial swelling, draining tracts, nasal discharge
- Tooth fracture

Equipment

The equipment used for equine extraoral dental radiology is generally the same that is used for radiographic examination of the horse for lameness: a portable x-ray generator is adequate. While standard film systems can be used, portable digital systems have distinct benefits for ambulatory practitioners:

- Multiple views and retakes can be anticipated in dental imaging; if processing in the field is not possible, the horse should be referred to a clinic where immediate processing can be performed.
- Similarly, intra- and postoperative images are often needed; without the ability to process the images in the field, the patient should be moved to a facility where this can be done at the time of the procedure.

Radiographic imaging systems presently available fall into 3 groups:

- Conventional film/rare earth cassettes and wet film processing.
- Computed radiography (CR) utilizing phosphor plates that are processed in a scanning device that generates a digital image.
- Direct radiography (DR) digital sensors that immediately generate a digital image.

The main disadvantage of traditional film is the inability to process the films in the field. For a clinic-based practice this is not a factor, and vinyl intraoral cassettes with rare earth screens can be purchased so that intraoral views of the maxillary cheek teeth can be obtained. The CR systems are portable, less than half the costs of the DR systems, but the image acquisition time is slower than the DR systems and they are more technique sensitive. In addition to the high cost, intraoral imaging of the cheek teeth is not possible with the DR sensors that are presently available.
Comparison of the 3 Systems

<table>
<thead>
<tr>
<th></th>
<th>Conventional Film</th>
<th>Computed Radiography</th>
<th>Digital Radiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Low</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Intraoral Imaging</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Image Quality</td>
<td>Good</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Radiographic Views/Positioning

Conventions and Labeling

The convention for presenting radiographic images of the dentition is somewhat different from that used by veterinary radiologists. As in human and small animal veterinary dentistry, the radiographs are presented as if a panoramic view of the dental arcades were being obtained. This standardized presentation eliminates the need for placing radiographic markers. However, since the digital imaging software may display the image incorrectly, requiring the clinician to rotate the image, an electronic label should be permanently imbedded in the DICOM image.

Incisors

The incisors are best viewed using intraoral placement of the cassette or digital sensor. Since the cassette/sensor is not parallel to the long axis of the incisor teeth, the bisecting angle technique is used to obtain an image of the teeth that minimizes foreshortening or lengthening of the image. Intraoral radiography in the horse requires sufficient sedation to eliminate chewing when the imaging cassette/sensor is placed in the mouth.

When the imaging plate cannot be placed parallel to the target tooth, the optimal image is obtained when the x-ray beam is directed 90° to the plane that bisects the angle between the target tooth and the plate (Fig. 1). In geriatric patients the inclination of the incisors diminishes, so that the bisecting angle decreases, and the x-ray beam approaches a perpendicular orientation to the plate.

Figure 1. The x-ray beam (red arrow) is directed perpendicular to the plane that bisects the angle formed by the target tooth and the imaging plate.
Standard views of the maxillary incisors are the intraoral straight and oblique occlusal views, with the beam centered on target incisor(s) (Figs. 2 & 3).

Figure 2. Intraoral views of the maxillary incisors of a 5-year-old horse: straight occlusal (far left) and oblique occlusal (middle and far right) views.

Figure 3. Intraoral views of the mandibular incisors (5-year-old horse): straight occlusal (far left) and oblique occlusal views (middle and far right).

**Canine Teeth**

The best images of the canine teeth are also obtained with intraoral placement of the film/plate/sensor. To image the maxillary canine tooth, the xray beam is centered on the canine tooth from the lateral aspect (perpendicular to the long axis of the head) and the at a 45 degree angle to the intraoral plate (Figs. 4 & 5).
Maxillary Cheek Teeth

The intraoral views of the maxillary cheek teeth are usually obtained with a full mouth speculum in place and a 4x8 inch vinyl cassette (film/intensifying screen or phosphor plate) placed across the palate and the occlusal surface of the cheek teeth. If the horse’s tongue is quiet, this cassette will stay in place. More often, it is necessary to keep the cassette from falling out by holding it with a long handled forceps or a notched 24 inch length of ½ inch PVC plumbing pipe (Fig. 6). The bisecting angle technique is also used when obtaining the intraoral views of the maxillary cheek teeth (Fig. 7). Since the long axis of the maxillary cheek tooth is almost 90° to the plate, the bisecting angle is about 45° to the imaging plate, with the beam centered on the target cheek tooth (or the rostral end of the facial crest, which marks the center of the arcade).
While the entire cheek tooth arcade is occasionally imaged with the intraoral technique, the 1<sup>st</sup> and 6<sup>th</sup> cheek teeth are often incompletely imaged or elongated (Fig. 8). The most informative radiograph is generally obtained when the x-ray beam is centered on the target tooth (Fig. 9).
Figure 10. Right maxillary cheek teeth of a 3-year-old. The image is foreshortened to include the apices of the long premolars. Note the absence of formed roots in the premolars. It is not possible to identify pulp horns and infundibulae due to the enamel infolding.

In a young horse, using the bisecting angle will frequently fail to image the apical region of these long teeth. In these horses it will be necessary to purposefully foreshorten the image (Fig. 10). It is often beneficial to obtain slightly off-angle views of the rostral or caudal cheek teeth in an effort to aim the beam through the interproximal space (Fig. 11). As the positioning is changed to optimize the image of individual maxillary cheek teeth, other teeth in the arcade will necessarily be distorted in the radiograph.

Figure 11. Demonstration of the change in rostro-caudal angle of the interproximal spaces of the maxillary cheek teeth.
The dorsoventral intraoral view, centered on the head at the level of the rostral end of the facial crest is useful for imaging the nasal passages, incisive, vomar and palatine bones (Fig. 12).

Figure 12. Comparison of the intraoral DV (left) and the extraoral DV views in a geriatric horse.

Extraoral views of the maxillary cheek teeth and associated sinuses are obtained with the imaging plate placed next to the target arcade. The straight lateral view will magnify the arcade closer to the x-ray generator, so any detailed apical radiographic anatomy of the superimposed teeth will likely be of the these cheek teeth rather than the arcade closer to the plate (Fig. 13). By convention, if the plate was placed next to the right side of the head, then the image is oriented for viewing so that the nose is to the viewer’s right. The straight lateral view is primarily used to evaluate the sinuses, and the technique should be adjusted to avoid “burnout” of these delicate bony structures (Fig. 13).

Figure 13. Left lateral extraoral view in a geriatric horse. The straight lateral view is of limited use in the evaluation of the cheek teeth due to superimposition. 1 infraorbital canals, 2 frontal/dorsal conchal sinuses, 3 rostral maxillary/ventral conchal sinuses, 4 caudal maxillary sinuses.
The dorsoventral oblique view with the beam centered on the apical region of the central maxillary cheek teeth is the standard survey image (Fig. 14). In most horses this will include the entire arcade. The maxillary and conchal sinuses have considerable overlap in the lateral and lateral oblique projections. The use of radiographic markers containing lead beads is recommended, so that the orientation of the head can be identified and correlated to suspected fluid lines (Fig. 15).

Figure 14. Open mouth DV oblique view of the right maxillary cheek teeth (geriatric horse). 1 Infraorbital canal, 2 caudal maxillary sinus/dorsal conchal sinus, 3 caudal maxillary sinus/ventral conchal sinus, 4 frontal sinus/dorsoconchal sinus, 5 rostral maxillary sinus.

Figure 15. The marker with metal beads (white arrow) identifies the orientation of the plate to the ground, and facilitates identification of the fluid line in the caudal maxillary sinus (black arrow).

The offset mandible DV is useful for imaging the maxillary arcade without the superimposition of the mandibular arcade. The horse must be adequately sedated so that when lead ropes are
placed in the mouth to draw the maxilla in the opposite direction from the mandible, chewing or head movement will not occur (Figs. 16 & 17).

Figure 16. Positioning for the DV offset mandible view of the right maxillary cheek teeth.

Figure 17. DV offset mandible view of the right maxillary cheek teeth (postoperative radiograph of 109 repulsion).

Figure 18. Intraoral views of the right mandibular cheek teeth of a 5-year-old (above) and the left mandibular cheek teeth of a geriatric horse (below).
Mandibular Cheek Teeth

The narrower space between the mandibular arcades and the thickness of the masseter muscles overlying the caudal mandible make imaging of the mandibular cheek teeth a challenging endeavor, especially with the CR systems. In most well-sedated horses, a 2.5x7 inch vinyl cassette can be inserted between the tongue and the mandible, adjacent to the lingual aspect of the mandible. This allows for a parallel technique, centered on the target tooth or mid-arcade. While this will not include the apical region of the mandibular cheek teeth in the young horse, it usually does include the clinical crown and most of the reserve crown and alveolar bone (Fig. 18). Although there will be some lengthening of the image, by changing the beam angle to a slightly VD oblique, an increased amount of reserve crown/root can be imaged.

The apical region of the mandibular cheek teeth can be imaged best with either a bisecting angle DV or a VD oblique view. For the DV view of the left mandibular arcade the plate is placed under the horse’s head as for a standard DV. However, since the long axis of the mandibular cheek tooth is about 90° to the plane of the plate, the beam is directed at about 45° to the imaging plate (perpendicular to the bisecting angle). Alternatively, the plate is placed parallel to the tooth, on the side of the horse’s head, and the beam is directed at a 60° VD oblique angle. (Fig. 19)

Figure 19. The mandibular cheek teeth can be imaged by using a DV bisecting angle technique (left) or with a VD oblique view (right).

The mandibular cheek teeth are difficult to image with current CR systems. The technique for the premolars often underexposes the molars. The thick soft tissue (masseter muscle) over the molars
often results in poor contrast of the caudal cheek teeth (Fig. 20). It is easier to obtain a diagnostic image of the mandibular cheek teeth with DR systems (Fig. 21).

![Figure 20. VD oblique view of the right mandibular cheek teeth in a 5-year-old horse.]

![Figure 21. The DR image (VD oblique) of the left mandibular cheek teeth. Fracture of the left mandibular 4th premolar (308).]

**Mixed Dentition**

Up until the full eruption of all the permanent incisors at age 4.5 to 5 years, the horse has a mixed deciduous and permanent dentition. As in other species, the permanent incisor erupt lingual to the deciduous counterpart. Persistent deciduous incisors result in liguoversion of the permanent successional tooth. Prior to extraction of these persistent deciduous incisors, intraoral radiographs are helpful in determining the anatomy of the deciduous incisor root, and post extraction films can confirm extraction of the entire root.

The permanent tooth develops within the dental sac. This cystic structure can be recognized on standard intraoral views of the incisors in horses with mixed dentition (Fig. 22).

The reserve crown, as determined by the presence of enamel, extends apically well below the gum line. The open apex of the young permanent incisor becomes a lateral foramen as the root, composed largely of cementum, develops. The number and location of apical foramina in the geriatric incisor is variable.

Figure 23. Cadaver specimen, 5-6-years-old. The development of the root of 301 has resulted in lateralization of the apical foramen (a). End-on view of the apical foramen of 302 illustrating that what appears to be a narrow circular apical foramen in the occlusal view is actually a flattened oval (b). The wide open apex of the less mature 3rd incisor, 403 (c).

Figure 24. Intra-oral radiograph of the maxillary incisors of a normal 6-year-old gelding. Open apex (1), infundibular enamel (2), infundibulum (3), root canal (4), periodontal ligament space (5), dentin (6) and enamel (7).

The canine teeth are frequently absent or rudimentary in the mare. Unerupted deciduous canine teeth may occasionally be seen in radiographs. Permanent canines are almost brachydont in their anatomy. The canine teeth can be imaged by both intraoral and extraoral techniques; however, the intraoral techniques are usually more detailed.

The maxillary cheek teeth consist of deciduous premolars and permanent molars with no deciduous precursors. In the young horse (less than 5 years of age), the mixed dentition of the cheek teeth can be evaluated using the open mouth oblique views (Figs. 25 & 26) or intraoral views.

Figure 25. Yearling Miniature Horse.

Figure 26. Maxillary cheek teeth of a 3-year-old horse. Note the long reserve crowns of the molars that largely fill the maxillary sinuses, and the premolar "caps."
When abnormal development and eruption of either deciduous or permanent cheek teeth occurs, associated clinical signs are common: facial swelling, nasal discharge, dysphagia, and draining tracts are the most common. Radiographic examination is key to the diagnosis and management of these cases.

Apical abscessation in young horses is frequently associated with the 4th premolars, which are the last permanent cheek teeth to erupt. It has been postulated that the eruption of the permanent 4th premolars in the space between the permanent 3rd premolar and the 1st molar results in some degree of impaction which sets up the right conditions for anachorectic infection of the apical portion of the pulp. This usually results in a ventral draining tract if the mandibular 4th premolar is involved, and facial swelling with nasal discharge or a facial draining tract when the maxillary cheek teeth are affected. This should not be confused with the normal “eruption cyst” frequently observed in 3-6-year-old horses (Fig. 27).

**Figure 27.** VD oblique view of the right mandibular cheek teeth of a 4-year-old horse. Note the artifactual lengthening of the cheek teeth and the eruption cyst of the permanent right 4th mandibular premolar (408), arrows.

**Further Examples of Dental Radiographic Pathology**  
*Figures 28 – 43*
Figure 28. Fracture-avulsion of the left maxillary deciduous 1st and 2nd incisors (602, 603). Normal dental sac (arrows) of 101. The left permanent incisors failed to develop in this colt after fracture repair (wires and acrylic).

Figure 29. Periapical bone lysis (arrow) blunting of the tooth apex, and widened root canal of a fractured left mandibular canine tooth with pulp necrosis.

Figure 30. This 3-year-old horse presented with right facial swelling and ocular discharge. Intraoral radiograph reveals abnormal development of the permanent right maxillary second premolar (106) with defects in the mesial reserve crown (black arrow) and apical bone lysis (white arrows).
Figure 31. Tooth resorption of the maxillary incisors (arrows). Also note the thickened and irregular periodontal ligament space around the maxillary 1st incisors (101, 201).

Figure 32. Right mandibular canine of a geriatric horse. There is marked resorption of the crown, arrow (left). Postoperative radiograph after surgical extraction (right).

Figure 33. Tooth resorption with marked hypercementosis in a geriatric horse.

Figure 34. Mule, 9-years-old. Crowded right mandibular incisors and rotated right 1st mandibular incisor.
Figure 35. Right lateral (above) and straight DV (below, left) and close up of the right DV oblique radiograph of a horse with right facial swelling. (Courtesy of Dr. Roy White).
Figure 36. Congenital absence of a right maxillary 3rd molar, with overgrowth of the right mandibular 3rd molar (arrow).

Figure 37. Thoroughbred mare, 15-years-old. Supernumerary left mandibular incisor.
Figure 38. Supernumerary 211. Stage 4 periodontal disease (attachment loss of >50%).

Figure 39. Large cystic structure associated with abnormal development of the right permanent maxillary 2nd premolar (106).
Figure 40. Fluid lines in the dorsal conchal (white arrow) and maxillary (black arrow) sinuses in a geriatric horse with left nasal discharge.

Figure 41. Ethmoidal hematoma (arrow) as seen in the left DV oblique view (left) and the intraoral DV (right).
Figure 42. Apical bone lysis and root resorption (arrow) of the mesial root of the left mandibular 1st molar (309). Grade 4 periodontal disease.

Figure 43. Stage 4 periodontal disease of the left maxillary 1st molar (209) in an 18-year-old horse. Periapical bone lysis, blunting of the tooth root and widening of the periodontal ligament space (arrows). Extraoral (above), and intraoral (below).
Beyond Radiographs: Advanced Imaging of Equine Dental Pathology

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Introduction

Diagnostic imaging is a critical tool for complete evaluation of oral health and disease in the horse. Even the most advanced oral exam using endoscopic techniques will not be able to determine the health of adjacent hard and soft tissue structures and the reserve crown and root located within the alveolus. Some equine teeth that appear normal on examination of the clinical crown can be the cause of regional sinusitis, impressive apical pathology, and fistula formation. Diagnostic imaging can help identify the tooth/teeth responsible for current clinical signs as well as provide additional information regarding the health of otherwise clinically normal teeth. Many times incidental pathology can be identified during imaging studies allowing the veterinarian to diagnose the current problem and to warn the owner of developing pathology.

Radiology is widely used, and the combination of view variety (extraoral and intraoral) and improved imaging systems has led to a renaissance in the practitioner’s ability to diagnose pathology with this modality. With the appropriate tools, adequate views, and experienced eyes, the majority of dental cases can be diagnosed with a complete oral examination and dental radiography. When radiography is not enough, four additional modalities can be utilized to provide additional information. Ultrasound, nuclear scintigraphy, magnetic resonance imaging (MRI), and computed tomography (CT) have all been used as ancillary techniques to either confirm or complete a diagnosis. CT has proven to be the most valuable of these four modalities to identify maxillofacial pathology providing accurate images in cross sectional and multiplanar views. Both soft and hard tissue algorithms with or without contrast provide ample information. Three-dimensional reconstructions are particularly useful for maxillary and mandibular fracture repair. The equipment and facility expense for nuclear scintigraphy, CT, and MRI programs usually restrict clinics, hospitals, and universities to providing one or two out of the three aforementioned modalities. Therefore, these facilities have become quite good at using the imaging system(s) available to identify pathology. With that said a handful of clinics and universities are using larger Tesla magnet MR systems adapted to handle equine limbs and heads. As a result, a new frontier of equine maxillofacial and mandibular imaging is being explored.

Ultrasound

Ultrasound is an excellent modality for imaging soft tissue structures. Its use is limited in dental applications due to regional bone overlying the tissues of interest. When bone destruction is extensive or masses lie superficial to the flat bones of the skull and jaw ultrasound can be used to help describe and determine the nature of these swellings. It can also be used to determine the
nature of soft tissue swellings of the cheek, tongue, orbit, and salivary gland. Numerous books and articles have been published on appropriate usage of this modality.

Nuclear Scintigraphy

Nuclear scintigraphy is unique among the imaging modalities because it allows for visualization of an active biologic process rather than a snapshot of structural anatomy. The third edition of Easley, Dixon, and Schumacher’s Equine Dentistry does a nice job of summarizing the use of nuclear scintigraphy in the horse for imaging of the head, specifically the teeth and sinuses. In short, an intravenous injection of a gamma ray-emitting radioisotope, $^{99m}\text{Tc-MDP}$, is used to detect regions of increased bone mineral turnover. Regions of increased radioisotope uptake appear darker on the scintigram and indicate active bone remodeling. Nuclear scintigraphy can image some bony pathology prior to its appearance in radiographic images as bone mineral turnover precedes structural change. Findings on the scintigram should always be evaluated with patient history, physical exam, and oral exam in mind as bone remodeling can be normal in certain circumstances such as growth, fracture repair, and alveolar remodeling post-extraction. If used to investigate pathology of dental origin, nuclear scintigraphy will readily identify regions of periapical disease and sinusitis. Various forms of neoplasia can also be imaged with this modality. Diagnosing additional dental pathology from a scintigram and/or determining a primary sinusitis from a tooth related sinusitis is often challenging and unrewarding. Therefore, nuclear scintigraphy is not usually the primary advanced imaging modality used for dental cases.

Magnetic Resonance Imaging (MRI)

Only a small handful of papers have been written evaluating or reviewing the use of MRI for evaluation of the equine head. Universities and equine hospitals using this modality for cranial and mandibular evaluations are also limited. Though MRI has been available to horses over the last decade the expense involved with equipment acquisition and facility preparation have hampered its popularity. In addition, MRI require longer general anesthesia times than computed tomography limiting the surgeon’s ability to image and operate on the same day due to concerns over excessively long anesthetic events. Facilities with MRI capability are usually functioning with a 1.5 Tesla magnet or better to produce diagnostic image quality. T1-weighted transaxial MR images are usually best for imaging the soft tissues of the cranial and mandibular regions. Bone and teeth have longer signal intensity and appear as dark regions. Soft tissues have higher signal intensities and appear lighter. This allows for excellent imaging of nerve, vasculature, pulp, periodontal ligament, temporomandibular joint, and adjacent soft tissue structures. Pathologic teeth can be identified by increased soft tissue surrounding teeth, decreased soft or hard tissue adjacent to teeth, pulp quality, and the reaction of sinus epithelium. Comparing structures bilaterally is essential for proper evaluation. As more institutions use this modality for dental evaluation, the value and advantage behind performing such an imaging study will become clearer.

Computed Tomography (CT)

Computed tomography in the horse is currently the best advanced imaging modality for dental pathology. In the third edition of Equine Dentistry, Drs. Simhofer and Boehler have written a
comprehensive review that details the technical principles of CT and the appearance of normal and abnormal dental tissue. Please refer to this review for detailed information and images. In the author’s experience, the vast majority of dental cases can be diagnosed with a thorough oral exam and high quality dental radiographs. When exam and radiographs don’t leave the practitioner confident about a diagnosis it is time for CT. CT provides excellent images of hard tissue and diagnostic images of soft tissue. The use of contrast, different algorithms, multiplanar views and three-dimensional reconstruction all work together to provide the practitioner with a diagnosis and confidence in treatment planning. Usually, pathology resulting in distinct clinical signs will be clearly evident on CT. Newer machines are producing images with such detail that the veterinarian and radiologist have to be cautious of over interpreting minor abnormalities and focus on major pathology. Very little literature has been published describing the newer high detail; multiplanar images and questions still remain about normal versus abnormal findings in some cases. The minor findings become more of an issue in cases with vague clinical presentations (e.g. discomfort with biting, plays with mouth, shakes head, carries head inappropriately) and a normal oral exam.

CT delivers the images necessary to identify the exact locations of pathology and the tooth/teeth associated with it. This can be particularly important in chronic sinusitis cases when radiographs may be inconclusive on tooth involvement. After years of evaluating CTs in only the cross sectional plane, the author has become particularly fond of multiplanar views. Cross sections are two dimensionally limited and three-dimensional reconstructions can be limited depending on the facility, technical acquisition of images, equipment limitations, and the radiologist processing the images. Multiplanar views have opened up a new world of three dimensional imaging and treatment planning for the surgeon. Borders of cysts, masses, thickened tissue, reactive bone, fracture placement, periodontal disease, diastema formation, infundibular carious lesions, apical pathology, and tooth fracture can all be triangulated with this capability. This enhances the veterinarian’s ability to diagnose abnormalities and plan for optimal treatments.

Most equine dental CT images are acquired first in a bone window with slice thickness ranging from 4 mm to 10 mm. This spacing results in roughly 3-4 cross-sections per tooth which is adequate for diagnosing major pathology, but sometimes will completely miss smaller lesions. Slice thickness ranging from 1 to 2 mm provides more information per tooth (5-7 slices/tooth) and should be used to examine teeth in detail. To emphasize the importance of smaller slice thickness and multiplanar views imagine a 3-4 mm wide periodontal defect in a diastema, a 2 mm congenital malformation along the full length of the crown, or a 2-3 mm diameter oronasal fistula. All can cause significant clinical signs and yet be invisible or near invisible on a routine 4 mm slice thickness cross sectional view, but these defects can be easily identified on transverse and sagittal multiplanar views. Needless to say, the temporomandibular joint should always be evaluated with decreased slice thickness and multiplanar views.

Since words can never provide as much information as pictures when reviewing CT images, the majority of the presentation will focus on normal and abnormal findings and case presentations. Please see the references below for further images and reading.

References


Addressing Pain: Regional Nerve Blocks

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Introduction

Providing adequate pain control for equine patients in the perioperative and postoperative period should be part of any veterinarian’s surgical plan in cases involving dental extraction and/or sinus surgery. The vast majority of extraction techniques in common use today can be performed standing with good perioperative analgesia/sedation delivered intravenously and analgesia provided by regional nerve blocks. This greatly reduces the risk to the horse from general anesthesia, bleeding during surgery and recovery time. Many same day surgeries can be performed stall side or with only a 24-hour stay at an equine hospital. In addition, postoperative pain control can improve the quality of patient recovery. Most equine owners have become quite savvy regarding pain control for their horses and will frequently want to discuss this issue with the practitioner.

There are many ways to provide analgesia and anesthesia for the horse intravenously or intramuscularly. These topics have been thoroughly covered in the 2010 Vet Clinics of North America: Equine Practice – Pain Therapy in Horses. In the words of Dr. Goodrich, “Pain that is controlled results in a nondepressed horse that maintains a good appetite and has a normal functioning immune system, which results in normal tissue healing.” The author highly recommends reading this issue of Vet Clinics to review the most recently reported literature on pre-, intra-, and postoperative pain control strategies using a multimodal approach to achieve maximal results.

One facet of a good pain control plan is regional nerve blocks. Regional nerve blocks are the key to being able to perform dental extractions in the standing horse under a constant rate intravenous infusion of a sedative agent. Prior to the common use of regional nerve blocks in performing standing extractions, the surgeon’s success relied more on the nature of the horse, very high doses of intravenous sedatives, and uncomplicated or nonsurgical extraction procedures. With the use of regional nerve blocks now most horses can have productive noninvasive and invasive dental procedures standing. General anesthesia is still necessary for intractable patients, surgeries requiring computed tomography, extractions or maxillofacial surgeries requiring precise delicate surgical techniques, and surgeries when the mouth cannot be opened (fracture repair, TMJ disease, masticatory muscle scarring, etc.) When placing a nerve block, achieving effectiveness while reducing risk is paramount. The following descriptions give step-by-step directions to performing nerve blocks associated with extractions. The maxillary nerve block has been anatomically researched and described by Dr. Staszyk, and he will present his technique in another session.
Materials and Methods

Local Anesthetic

- Major Procedures: Bupivacaine 5% solution (Marcaine)
  - onset of action 10-20 minutes
  - duration of action 180-480 minutes
- Minor Procedures: Lidocaine 2% solution
  - onset of action 1-3 minutes
  - duration of action 60-120 minutes
- Give all regional anesthetics slowly (over 1 minute) and choose the volume appropriate for the site (avoid placing too much in a restricted space).

Materials Needed

- Clippers
- Betadine and saline soaked gauze for prep tray
- Sterile gloves
- Tuohy Epidural Needles (spinal needles used historically)
  - 3.5” length; 22 gauge
  - 6.0” length; 20 gauge
- Hypodermic needle
  - 1.0” length; 25 gauge
  - 1.5” length; 24 gauge
- Extension set 6” luer lock
- Syringe
  - 20cc luer lock
  - 12cc luer lock
  - 3cc
- Black Sharpie pen
- Peripheral nerve stimulator (BBraun DIG RC)
  - Insulated peripheral nerve block needle 6” length and 20 gauge (Stimuplex A insulated needles by BBraun )
  - Conducting gel

General Preparation

- Heavily SEDATE the horse!!!
- Block site is located.
- Hair is clipped from injection site.
- Injection site is marked with Sharpie.
- The skin is surgically prepared.
- Fill syringes with local anesthetic and flood extension lines if used.
- Sterile gloves are worn for injection.

Inferior Alveolar Nerve Block (Mandibular Nerve Block)
The inferior alveolar nerve block anesthetizes the inferior alveolar nerve as it branches away from the mandibular nerve and travels into the mandibular foramen and the mandibular canal. This block will provide analgesia to the ipsilateral mandible and mandibular teeth in addition to all soft tissue structures innervated by the mental nerves (see below). The mandibular foramen is located rostrally on the medial aspect of the coronoid process at the level of the ipsilateral mandibular occlusal surface.

- Locate the mandibular foramen at the intersection of the following two lines:
  - Lay a straight edge along the occlusal surface of the mandibular cheek teeth. The most caudal portion of the commissure of the lips usually corresponds to this surface and the line is drawn parallel to the facial crest. Mark with a Sharpie the portion of this plane over the masseter muscle.
  - Lay the straight edge from the lateral canthus of the ipsilateral eye to the most ventral aspect of the mandibular ramus and mark with a Sharpie the plane over the masseter and the intersection point with the preceding plane.

- Once the site is prepped, hold the 6-inch needle to be used above the skin in the premarked vertical plane to measure the distance on the needle from the ventral aspect of the ramus to the mandibular foramen.

- Perform block with or without the assistance of a nerve stimulator.

- If no nerve stimulation guidance is chosen, use the 6 inch 20 gauge Tuohy needle to perform the block. Use of an extension set is recommended for ease. Positioning of the needle and delivery of local anesthetic is the same for stimulation-guided and non-guided blocks.

- For use with a nerve stimulator:
  - Connect 6 inch insulated nerve block needle to unit and second contact to horse.
  - Initially set unit at 1mA and 1 Hz. This is well tolerated by sedated horses.
  - The needle is introduced ~2cm lateral from the midline of the intermandibular space at the most ventral aspect of the ramus.
  - The needle is directed towards the medial aspect of the coronoid process at a 30 to 45 degree angle.
  - When the needle contacts bone redirect the needle in a more parallel plane to the coronoid process and try to keep the needle constantly in contact with the bone while sliding dorsally.
  - As you get close to the mandibular foramen, twitching of the mylohyoid muscle and the digastricus muscle may be evident.
  - Once you reach the premeasured length of the needle, a chomping of the teeth (masticatory reflex) in rhythm with the stimulation will indicate proximity of the inferior alveolar nerve. Turn the unit to 0.5mA to more precisely locate the nerve.
  - The syringe is aspirated to ensure no direct placement in a vessel. Inject 10-15cc of local anesthetic slowly.
  - If no chomping reflex is elicited, carefully redirect or advance the needle until the reflex is stimulated. Avoid making wide excursions with the needle, so if necessary, completely remove the needle and attempt a slightly different angle/placement of approach.

- The use of the nerve stimulator gives the clinician confirmation of appropriate deposition of local anesthetic while minimally affecting adjacent nerves like the lingual nerve.
Mental Nerve Block

The mental nerve block anesthetizes the rostral portion of the inferior alveolar nerve as it branches into the mental nerve at the level of the mental foramen. If the block is delivered to the rostral inferior alveolar nerve, then the ipsilateral canine and incisor teeth will be anesthetized in addition to the skin and lip rostral to the mental foramen. Only the mental nerve (skin and lip) will be anesthetized if the local anesthetic is not delivered through the mental foramen into the mandibular canal. The mental foramen is located on the lateral aspect of the mandible in the interalveolar space (the “bar”) at the level of the commissure of the lips halfway between the most dorsal and ventral aspect of the mandible. Dorsal elevation of the tendon of the depressor labii inferioris, which lies over the foramen, will assist with palpation.

- Locate the position of the mental foramen.
- Clip, clean, and prep site.
- Use a 1.5-inch 24-gauge needle for this block.
- Palpate the foramen. Introduce the needle roughly 1 cm rostral to the foramen at a 30 to 40 degree angle to the bone.
- The needle is passed into the foramen roughly 1 cm and digital pressure is applied to the mental foramen to stabilize the needle and prevent outflow of local anesthetic.
- The syringe is aspirated to ensure no direct placement into a vessel.
- Slowly deposit 5 mls of local anesthetic. If in the mandibular canal, avoid placing too much fluid (>10 mls) in the canal as this may result in nerve damage due to high pressure within the canal.
- Slowly remove the needle and apply pressure to the site for roughly 1 minute.

Infraorbital Nerve Block

The infraorbital nerve block anesthetizes the infraorbital nerve as it exits the infraorbital foramen. This block provides anesthesia to the ipsilateral canine, incisors, and the skin, lip, nostril, and face up to the level of the infraorbital foramen. It is debatable if this block provides any anesthesia to the second and third premolar. If the block is placed into the infraorbital canal the premolars and rostral molar teeth may also obtain adequate anesthesia. The infraorbital foramen is located dorsal and rostral to the point of the facial crest on the maxillary bone.

- Locate the position of the infraorbital foramen at the intersection of two lines.
  - Draw an imaginary line from the lateral canthus of the eye down the maxilla parallel to the facial crest.
  - Draw a second imaginary line 1 to 2 cm rostral to the point of the facial crest that is perpendicular to the facial crest.
  - The infraorbital foramen will be located beneath the ventral margin of the levator labii superioris muscle. Move this muscle dorsally to palpate the foramen ridge.
- Clip, clean, and prep the site.
- Use a 3.5 inch 22 gauge Tuohy needle for this block.
- Introduce the needle as flush to the maxillary bone as possible roughly 0.5 cm rostral to the foramen. Keep the angle of the needle parallel to the facial crest to avoid hitting the walls of the infraorbital canal.
The needle can be advanced to the desired length up to 2.5 inches to achieve necessary anesthesia. It is the author’s opinion that the needle should only be advanced 1 cm to avoid damage to the neurovascular bundle in the canal. If more caudal analgesia is necessary the author recommends using the maxillary nerve block described by Dr. Staszyk.

Once the needle is in the canal, digital pressure is applied to prevent outflow of the local anesthetic.

The syringe is aspirated to ensure no direct placement into a vessel.

Slowly inject 5 mls of local anesthetic into the canal. Avoid placing too much fluid (>10 mls) in the canal as this may result in nerve damage due to high pressure.

Slowly remove the needle and apply pressure to the site for roughly 1 minute.

**This block is NOT well tolerated by the horse due to the almost unavoidable direct needle contact with the nerve**

**Supraorbital Nerve Block**

The supraorbital nerve block anesthetizes the supraorbital nerve a branch of the ophthalmic nerve off the trigeminal nerve. Blocking the supraorbital nerve will provide anesthesia to the forehead and the middle two thirds of the upper eyelid. The location of the nerve is found at the level of the supraorbital foramen, which can be palpated about 5 to 7cm dorsal to the medial canthus of the eye.

- Location of the supraorbital foramen can be found by pinching the supraorbital process of the frontal bone with thumb and middle finger and sliding medially. The index finger will easily fall into the relatively large depression of the supraorbital foramen.
- Clip, clean, and prep site.
- Insert a 25-gauge one-inch needle into the foramen. The needle is held perpendicular to the skin and then angled slightly in the rostral direction upon insertion.
- Aspirate to ensure needle is not located in a vessel.
- Superficially deposit 1 ml of local anesthetic at the opening of the foramen.
- Continue to sink needle to its hub for injection within the foramen. Once fully inserted, inject 2 mls of local anesthetic into the site.
- Remove needle and apply digital pressure for roughly 1 minute.

This block is most commonly used for sinus surgery involving a frontonasal flap.

**Infrafrochlear Nerve Block**

The infratrochlear nerve block anesthetizes the infratrochlear nerve, a branch of the ophthalmic nerve off the trigeminal nerve. Blocking the infratrochlear nerve will provide anesthesia to the medial canthus of the eye and skin extending ventral and rostromedial to almost the level of the infraorbital canal.

- Location of the infratrochlear nerve is found by palpating the irregularly shaped notch on the dorsal rim of the orbit near the medial canthus of the eye.
- Clip, clean, and prep site.
- A 25-gauge one-inch needle is used for the block. The needle is held at a 30 degree angle to the skin with the needle tip directed dorsally towards the knotch. Advance needle to location of knotch.
- Aspirate to ensure needle is not located in a vessel.
- Slowly deposit 3 ml of local anesthetic at the level of the knotch.
- Remove needle and apply digital pressure for roughly 1 minute.

This block is most commonly used for sinus surgery involving a frontonasal or maxillary flap.

**Discussion**

The choice of local anesthetic agent depends mostly on the duration of action the practitioner hopes to achieve. As the use of narcotics is less desirable in the horse due to decreased gastric motility and the risk of colic, it is desirable to use a local anesthetic that will work for as long as possible to help provide postoperative analgesia. Local nerve blocks should be performed prior to performing surgery or extracting teeth, and depending on the length of surgery, providing a second block prior to recovery can be beneficial postoperatively. The following is a passage out of Lumb and Jones’ Veterinary Anesthesia and Analgesia, “The mechanism of action is the same for all local anesthetics, that is, interruption of the propagation of impulses along peripheral nerves preventing noxious stimulation from being transferred and causing complete analgesia in tissues. These agents bind to sodium channels and prevent depolarization. When used operatively, they can decrease the response to painful surgical stimuli and decrease the amount of general anesthesia needed to maintain a desirable plane of anesthesia. If a local block is being performed not only to decrease surgical stimulation but also to assist with recovery and to provide continued analgesia during the postoperative period, bupivacaine should be used based on its extended time of action (6–8 hours).” The author has found bupivacaine to be an excellent local anesthetic for maxillofacial and dental procedures. Though its onset of action is longer than other local anesthetics (10-20 minutes), the lag time can be minimized by placing the block prior to any surgical preparation or oral manipulation. In addition, research is starting to reveal the benefit of combining an alpha-2 agonist with local anesthetics to increase the duration of the block. Combining 0.1ml of 50 mcg/ml dexmedetomidine for every 10 mls of local anesthetic could potentially double its duration of action though no clinical trials in horses have been performed yet to prove the theory.

Neurovascular damage is a major complication that can occur with the use of regional nerve blocks. This is particularly important when entering tight canals or regions packed with major vessels and nerves. Conventionally used spinal or hypodermic needles cut through these structures. Using needles specifically designed for nerve blocks and decreasing needle size helps reduce this risk. The smallest possible gauge needle should always be used to minimize nerve and vessel laceration. The tip of Tuohy needles (recommended above) have a rounded bevel with cutting edges off to the side; therefore, these needles are more likely to push the vasculature and nerves away from the needle tip. The blunter end of the Tuohy needle also provides increased tactile feedback. This becomes a major advantage when placing the maxillary nerve block as it helps identify the distinct “pop” associated with the most medial fascial plane of the masseter muscle.
The inferior alveolar nerve block described above includes the use of a nerve stimulator. Using the peripheral nerve stimulator to guide precise placement of the local anesthetic helps to decrease the amount of local anesthetic necessary to achieve an adequate block. The masticatory reflex or chomping-like action produced by stimulation of the mandibular nerve is caused by the contraction of the masticatory muscles with motor innervation from a branch of the mandibular nerve. With precise placement and decreased amounts of local anesthetic, the risk of unintentionally anesthetizing or damaging the lingual nerve is minimized. Damage and/or anesthesia of the lingual nerve has always been a major concern when performing the inferior alveolar block blindly and with 20-30 mls of local anesthetic. Numb tongues are at risk of maceration by the patient, and extensive damage to the tongue has been reported after performing a blind inferior alveolar nerve block. The nerve stimulator also gives the practitioner confirmation that the inferior alveolar nerve block has been placed appropriately and will provide anesthesia of the nerve. Peripheral nerve block stimulators can be purchased for less than 500 dollars, and the cost of the insulated needles is approximately 25 dollars per needle. These costs can be passed on to the owner by charging appropriately for regional analgesia. If no nerve stimulator is used, then the author highly recommends the use of a 6-inch Tuohy needle for this block.

Both the infraorbital and mental nerve blocks are not well tolerated by horses invariably due to the contact of the needle with the nerve. Some authors have suggested using a lidocaine block superficially and around the foramen prior to attempting the block inside the canals. It is the experience of the author that even these superficial blocks result in head tossing, and they decrease the palpability of the necessary foramen. Placing these blocks even in heavily sedated horses can be very frustrating for the horse and veterinarian not to mention the pain for the horse associated with needle-nerve contact. An additional complication associated with the infraorbital block is leaching of the local anesthetic into the region of the levator naso-labialis. This will result in decreased aperture of the ipsilateral nasal opening and decreased airflow. The lateral nasal wall does not become completely flaccid due to the functioning of the dilatator naris lateralis, but blocking both left and right infraorbital nerves at the same time is discouraged for this reason.

The author believes that the safety and efficacy of performing the maxillary nerve block discussed by Dr. Staszyk and the nerve stimulation-guided inferior alveolar nerve block are completely sufficient for providing anesthesia for the maxillary and mandibular teeth, alveoli, and gingiva. Horses react only mildly to these blocks with slight head movements; not the extreme head tossing stimulated by the mental and infraorbital blocks. For this reason the author relies primarily on the maxillary and inferior alveolar nerve blocks to provide dental anesthesia. Both the supraorbital and infratrochlear nerve blocks are well tolerated by horses and can significantly help provide regional anesthesia for paranasal sinus surgery.

References


Infraorbital Nerve Block Within the Pterygopalatine Fossa - EFBI-Technique

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Take Home Message

Regional anesthesia of the infraorbital nerve within the pterygopalatine fossa provides excellent analgesia of maxillary teeth. The extraperiorbital fat body insertion - technique (EFBI-technique) provides sufficient analgesia with a minimized risk of damaging relevant nerves and blood vessels.

Introduction

For extensive oral surgical procedures, e.g. extraction of cheek teeth, chemical sedation, regional anesthesia, and sufficient analgesia of the horse are required. Desensitization of the maxillary cheek teeth is achieved by local blocking of the infraorbital nerve within the pterygopalatinal fossa.\textsuperscript{1-4} Several complications, such as hematoma, exophthalmos, and blindness have been observed after application of this technique.\textsuperscript{3} Even fatal neurological deficits due to ascending infections are described.\textsuperscript{1}

In order to eliminate these risks it has been suggested to inject the anesthetic into the extraperiorbital fat body (EFBI-technique).\textsuperscript{5} Thus, the inserted needle does not reach relevant blood vessels and eye associated structures. Therefore the infiltration of an anesthetic was simulated by injecting a contrast medium in cadaveric heads and living horses under general anesthesia. While the effective spread of the injected contrast medium was demonstrated using computed tomography, sufficient regional anesthesia and analgesia using the EFBI-technique was only assumed in this study.\textsuperscript{5} Therefore a clinical evaluation of the EFBI-technique has been performed in order to assess effectiveness and risks under clinical conditions. Two parallel studies (referred to as A and B) were conducted. The objectives of study A were to:

- evaluate the practicality of the EFBI-technique in sedated horses under clinical conditions,
- re-examine the risks and side-effects of the EFBI-technique,
- evaluate methods for testing adequate analgesia of teeth and gingiva,

The objective of study B was to:

- evaluate the efficacy of the EFBI-technique using two different volumes of lidocaine under surgical conditions.
Material and Methods

Studies (A and B) were designed as randomized prospective, blinded clinical trials. For this purpose, the horses were sedated and received either 2 or 4 mL/100kg of an anesthetic (2% lidocaine) using the EFBI-technique (either left or right side of the head).

For study A, 20 experiments were performed. Anesthesia was not followed by any surgical intervention. Behavior and clinical parameters of the horses as well as clinical side effects were recorded for a period of 72h.

For study B, 80 horses with a proven indication for the extraction of a maxillary cheek tooth were sedated and regionally anaesthetized (EFBI-technique, either 2 or 4 mL/100kg of 2% lidocaine) followed by oral extraction of a diseased maxillary cheek tooth.

Results

The EFBI-technique appeared to be appropriate for providing a sufficient nerve block with minimal risk of complications.

- The anesthesia within the extraperiorbital fat body was well accepted in all horses.
- Minimal incidents like chewing or marked head movements were observed during the performance of the local nerve block.
- Differences in behavior of the horses during tooth extraction between the two volumes of lidocaine were not significant.
- Immediately following the nerve block, temporary extraperiorbital hematoma and corneal ulceration occurred in three horses (out of 80 horses) which received the higher volume (4 mL/100kg) of the anesthetic.
- Based on the data of Schirmer tear tests there was no significant difference between the lacrimal fluid on the anesthetized head side before and after the local nerve block. The data indicated a decrease of the lacrimation rate after anesthesia, but the results were statistically insignificant.

Conclusion

The suggested EFBI-technique using 2 mL/100kg lidocaine 2% provides safe and effective regional anesthesia while extracting maxillary cheek teeth. A preventive treatment with eye ointment is recommended. Methods for the evaluation of the efficacy of analgesia in maxillary cheek teeth need to be refined and developed in future studies.

References

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Further Reading


Developmental Craniofacial Abnormalities and Disorders of Development and Eruption of the Teeth

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Craniofacial Abnormalities

Foals can develop a number of developmental abnormalities of their craniofacial bones that cause dental malocclusion and dysfunction. Although some of these abnormalities such as overjet and overbite (“parrot mouth”) are often regarded as being primary dental abnormalities, these dental abnormalities are just one manifestation of an underlying craniofacial skeletal abnormality. Consequently, correction of the dental abnormalities, such as reducing dental overgrowths, will not affect the underlying craniofacial abnormality.

Overjet and Overbite

Many horses have some degree of overjet, (“overshot jaw”) i.e. where the occlusal aspects of the maxillary incisors lie rostral to the occlusal aspects of the mandibular incisors.¹ If very marked and untreated, cases of severe overjet will often develop overbite (“parrot mouth”) where the upper incisors lie rostral to the mandibular incisors as above but also now lie in front of the erupted crowns mandibular incisors due to marked overgrowth of the premaxillary incisors and/or to ventral curvature of the premaxillary (incisive) bones due to absence of occlusal contact. Overjet and overbite are aesthetically undesirable but surprisingly, these problems rarely cause difficulty in prehension. As the more rostrally situated incisors (01s) have the least occlusal contact, they overgrow most and so affected horses develop a convex appearance of their premaxillary incisor occlusal surface (“smile”), which should be gradually reduced in stages if it is pronounced. The main clinical significance of incisor overjet or overbite are the concurrent CT disorders usually present, due to the maxillary CT row being rostrally positioned in relation to the mandibular CT row as discussed below.

Underjet

Underjet (prognathism, “undershot jaw”, “sow mouth”) is rare in horses (more common in donkeys) and like overjet is usually clinical insignificant unless there is complete absence of occlusion between the incisors. Horses with underjet usually develop focal CT overgrowths on the caudal aspects of the maxillary 11s and the rostral aspects of the mandibular 06s. Similar to overjet/overbite, concurrent CT focal overgrowths are the main clinical problem with underjet and such CT overgrowths should be monitored at 6-month intervals.

Rostral Positioning of the Maxillary CT Rows

Rostral positioning of the maxillary CT rows relative to their mandibular counterparts is caused by an imbalance between maxillary/premaxillary and mandibular bone growth and as noted, is
nearly always associated with incisor overjet/overbite. Occasionally, this abnormality can be present without incisor malocclusions. Because the maxillary and mandibular CT rows are not in full occlusion, localised CT overgrowths (colloquially termed “beaks”, “hooks” and “ramps”) develop on the rostral aspect of the maxillary 06s. These overgrowths may be pushed against the lips and cheeks by the bit/noseband and so cause mucosal ulceration and biting problems. If large, these overgrowths can also restrict the normal, but variable, rostro-caudal mandibular movement, relative to the maxilla, while lowering and raising the head. Feeding affected horses fully from the ground rather than from a height may increase normal rostro-caudal mandibular movement and reduce the development of such overgrowths. Large 06 overgrowths should be removed (not necessarily fully if very tall) in stages to prevent pulpar exposure or overheating.

Similar overgrowths usually develop on the caudal aspect the mandibular 11s that can traumatis the adjacent oral mucosa, but due to the later eruption of the 11s in comparison to the 06s, the caudal overgrowths may not develop until 5-6 years of age. True mandibular 11 caudal overgrowths must be differentiated (e.g. by assessing crown height above the gingival margin) from anatomically normal, upward sloping caudal CT occlusal surface (“curve of Spee”), which can be marked in some breeds.

Larger mandibular 11s overgrowths are best reduced in stages using motorised dental instruments, whilst maintaining the normal high occlusal angulation of caudal mandibular CT. ‘Molar cutters’ or percussion instruments can fracture the overgrown tooth causing pulpar exposure, that can lead to apical infection or even extensive infection of the mandibular and adjacent areas.

**Wry Nose (Campylorrhinis Lateralis)**

Wry nose is a syndrome involving lateral deviation and possibly shortening of the premaxillary (incisive) and maxillary bones, and can less commonly involve the nasal and vomer bones. Malocclusions of the incisors and of the CT at the extremities of the CT rows can occur. Milder cases will later develop a diagonal incisor occlusal plane (“diagonal bite”, “slope mouth”, “slant mouth”) with one incisor arcade permanently displaced to one side and unilateral maxillary 06, and mandibular 11 CT overgrowths. Surgical correction is possible up to about one year of age. Incisor and CT overgrowths should be assessed at 6 month intervals.

**Disorders of Dental Development**

**Hypodontia (Anodontia)**

Hypodontia is a failure of differentiation of the dental lamina and tooth germs for the deciduous and/or permanent teeth - in contrast the presence of supernumerary teeth is due to the development of too many dental buds. Developmental hypodontia is relatively uncommon in horses, with absence of equine teeth usually due to traumatic loss, disease or to age-related wear. True hypodontia generally affects the permanent equine dentition. In many species (including the horse) multiple hypodontia is often associated with the presence of other dental abnormalities (such as dysplastic teeth) or even generalised ectodermal disorders involving the hair and hoofs.
The development of an overgrowth on the opposing tooth is often the first indication of hypodontia.

**Supernumerary Teeth (Polydontia)**

The presence of supernumerary (additional) teeth is relatively uncommon in horses, usually developing in the permanent dentition. Single supernumerary teeth can be categorized into three types, i.e. **Supplemental** (similar to normal teeth); **Haplodont** (simple conical shape) or **Tuberculate** (complex shape). They also may be composed of more than one tooth joined together (**connate or double tooth**).5

**Supernumerary Incisors**

Equine supernumerary incisors may be more common (or possibly more readily identified) than supernumerary CT. Equine supernumerary incisors can vary in number from 1-6 and are usually of normal morphology (supplemental) and so can be confused with retained deciduous incisors, but radiography will usually distinguish between them. Supernumerary incisors may cause overcrowding and displacement of the normal incisors, and diastemata often occur beside displaced incisors.5 If the supernumerary incisors lie rostral (labial) to the normal incisor arch, it is usually possible to extract them but if interwoven amongst the other incisors, differentiation of supernumerary teeth and safe extraction may be impossible. The incisors should regularly be assessed for periodontal disease and protruding overgrowths that may cause soft tissue trauma. Protruding incisors should be monitored biannually, preferably using motorised equipment.5

**Supernumerary Canine and 1st Premolar Teeth ("Wolf Teeth")**

Supernumerary canine or first premolar teeth rarely occur. Most suspected supernumerary canines are in fact rostrally displaced, large “wolf teeth”. Radiography will readily differentiate between these types of teeth. Many suspected supernumerary “wolf teeth” are retained fragments of the deciduous 06, that are flattened, superficial structures that are readily removed.

**Supernumerary Cheek Teeth**

The most common site for supernumerary CT development in horses is as noted, the caudal aspect of the maxillary 11s and less commonly mandibular 11s. Supernumerary CT may also develop medial, lateral or rostral to the maxillary or mandibular CT rows.5-7 There is often overcrowding and/or the presence of irregular interdental margins associated with supernumerary CT and the resultant large interdental (interproximal) space (i.e. diastemata) lead to food pocketing and often painful periodontal disease. Additionally, continued eruption of unopposed supernumerary CT causes an overgrowth (usually at the caudal aspect of the CT rows). Consequently, it should always be determined if caudal overgrowths are Triadan 11 overgrowths or supernumerary CT. Treatment includes oral extraction, widening or filling of diastemata or continuous reduction of overgrowths.5

**Dental Dysplasia**

Dysplasia or abnormal development of teeth can involve the crown, roots or all parts of the tooth. Dysplasias in the gross anatomy include dilacerations (abnormal bending of teeth), double teeth,
Abnormalities of size and concrescence (roots of adjacent teeth joined by cementum) of teeth.\textsuperscript{3,5,8} Other dysplastic teeth will be of normal morphological structure and of normal shape but will be excessively large i.e. \textit{macrodontia} or too small, i.e. \textit{microdontia}. Disturbance in the structure of teeth include dysplasias (disturbances of development) of the individual calcified dental tissues or pulp. In human dentistry, there is now much knowledge of the genetic defects causing some dental dysplasias.

Amelogenesis imperfecta include a range of hereditary disorders affecting enamel formation in both deciduous and permanent teeth and can be divided into two types, i.e. defects in enamel matrix formation or in the mineralisation of enamel. Amelogenesis imperfecta as part of a generalised ectodermal syndrome has been described in a horse.\textsuperscript{4} A wide range of developmental defects of dentine have been described in humans including dentinogenesis imperfecta and others caused by mineral and vitamin deficiencies.\textsuperscript{3} Developmental cemental defects are uncommonly found in any species. Root hypercementosis, (increased deposition of cement on roots) is a feature so commonly found in older equine teeth to be almost regarded as physiological. Marked hypercementosis is also present in some chronic equine CT apical infections.

\textbf{Abnormalities of Dental Eruption}

\textit{Maleruption of Cheek Teeth}

Some cases of “stepmouth” and “wavemouth” are caused by mismatching of eruption times of opposing permanent CT, allowing overgrowth of the teeth which erupt first.\textsuperscript{5} Bilateral overgrowths the maxillary 10s are a common pattern of this disorder in some breeds. These developmental overgrowths may remain for life and even increase in size with time, and later initiating further abnormalities of CT wear and diastemata. Recognising and removing such overgrowths at an early stage (in stages if necessary) is the key to their management.

\textbf{Retention of Deciduous Teeth}

\textit{Retention of Incisors}

Deciduous incisors are occasionally retained for a significant period beyond their normal time of shedding, which is approximately 2.5, 3.5 and 4.5 years of age, respectively, for the 01s, 02s and 03s and the deciduous and permanent teeth then occupy the same tooth position. Retained incisors are usually displaced labial (rostral) to the erupting permanent incisors or they can lie between and displace the permanent incisors. Rarely, incisors are displaced on to the lingual aspect of the permanent incisors. It can sometimes be difficult to assess if additional teeth in the arcade are supernumerary incisor.\textsuperscript{5} Radiographs should be taken prior to attempted extraction of any additional incisor, unless it can be positively identified on morphological appearance as being a retained incisor.

\textit{Retention of Cheek Teeth}

Abnormal retention of the remnants of the deciduous CT (termed “caps”) can occur in horses between 2 - 4.5 years of age but there is much individual variation in the timing of deciduous
cheek tooth shedding. If the deciduous teeth become very loose they may tear periodontal ligaments or gingival attachments during eating, causing oral discomfort for a couple of days. Clinical signs of oral discomfort in 2-4-year-old horses warrant careful oral examination for evidence of deciduous teeth that are loose or have a distinct space between them and the permanent teeth.

The practice of methodically removing deciduous teeth at set ages will result in the premature removal of deciduous CT in some horses. Once the deciduous tooth is removed, the fleshy dental sac covering the underlying developing permanent cheek tooth is exposed and quickly destroyed by mastication. This will lead to loss of blood supply to the occlusal aspect of the infundibula of the rostral 3 maxillary CT where active cement deposition may still be occurring. This may result in marked central infundibular cement hypoplasia and so predispose to the development of infundibular caries later in life.

**Vertical Impaction of Cheek Teeth (“Eruption Cysts”; “3-Year-Old and 4-Year-Old Bumps”)**

As noted in the pervious section, many horses develop focal, bilateral swellings of their mandibles and also less obviously (due to the presence of overlying muscles) of their maxillae beneath the developing apices of the 07s and 08 CT. Certain breeds, especially lighter breeds and miniature horses in particular, are more prone to develop these bony swellings. These eruption cysts may be due to vertical impaction of the CT that erupt last, but with time, as the mandible and maxillae lengthen, the impacted CT have room to erupt normally and the overlying bones remodel to a normal contour over the following year or so.

**Developmental Diastema(ta)**

The occlusal surfaces of the individual CT rows are normally compressed tightly together so that the occlusal surface of the 6 CT in each row function as a single grinding unit (Fig. 1).

![Normal CT Occlusion](image)

*Figure 1. Normal CT occlusion.*

However, if spaces, i.e. diastema(ta) develop in the interdental (interproximal) space between the CT, food impaction will occur in these spaces. Developmental mechanisms that can allow
CT diastemata to develop⁷,¹⁰ include inadequate angulation of the rostral (06s) and caudal (10s, 11s) CT that normally compress the occlusal aspects of all 6 CT together (Fig. 2). Alternatively, CT may have normal angulation but develop too far apart due to disparity between size of teeth and supporting bones or because the CT buds develop too far apart (Fig. 3).

**Figure 2. Reduced CT angulation.**  
**Figure 3. CT angulation normal, CT too far apart.**

*Valve diastemata* where the abnormal interdental space is narrower at its occlusal than gingival aspect are more problematic than *open diastemata* where the abnormal space has similar width from the occlusal surface to the gingiva. du Toit, et al has shown that clinical examination of diastemata can be accurately differentiated between valve diastemata or open diastemata with mean occlusal to gingival diastema width ratios of 0.4 found in valve diastemata and of 1.07 in open diastemata.¹¹

The massive and prolonged forces of mastication on equine CT occlusal surfaces cause progressively deeper impaction of long fibres into widened interdental space which can later spread sub-gingivally to the lateral and medial aspects of the two affected teeth. This leads to a painful and usually progressive secondary periodontal disease with remodelling and lysis of the alveolar bone - that occasionally may even lead to extensive osteomyelitis of the supporting mandibular or maxillary bones or if involving the maxillary 08s-11s, to sinusitis or an oromaxillary fistula - with the overlying maxillary sinuses becoming filled with food and exudate. CT diastema can be recognised by finding food fibres packed in between teeth and more significantly in periodontal pockets between the CT just above the gingival margin, especially between the caudal mandibular cheek teeth (09s-10s; 10s-11s). Due to their common position between the caudal mandibular CT where they are hidden by the tongue, mandibular CT diastemata are difficult to clinically detect unless these sites are carefully examined with an intraoral mirror or endoscope.

The main consequence of CT diastemata is periodontal disease which is discussed in a further abstract.

**Developmental Displacement of Teeth**

*Displacement of Incisors*
In addition to displacements in the presence of supernumerary incisors, occasionally gross displacement of permanent incisors can occur in horses with a normal number of teeth. Previous trauma may have displaced the buds of the developing permanent incisor(s), but they also may be displaced because of intrinsic developmental reasons.

Displacement of Cheek Teeth

Displacements are rare in deciduous equine CT, but are common in permanent CT. Two different types of permanent CT displacement (i.e. developmental and acquired) are recognised in horses. Most severe CT displacements, especially in younger horses, are developmental and often appear to be caused by overcrowding of the dental rows during eruption and less commonly, by developmental displacement of the CT buds. Developmental CT displacement may be bilateral, and displaced CT may be bent suggesting that dental overcrowding occurred prior to calcification of the developing tooth. Jaw trauma can also damage or displace a developing CT bud, causing later maleruption.

The 09 and 10 positions are most commonly displaced, and equine mandibular CT are three times more likely to be displaced than maxillary CT. Large overgrowths can develop on aspects of displaced and their opposing teeth, that are not in occlusal contact. More importantly, displaced CT invariably have diastemata beside them (Fig. 4) which allows painful food pocketing. Marked displacements where CT lay horizontal in the mandible or the maxilla and never erupted have been reported.

Abnormal protrusions or overgrowths of displaced and opposing CT should be reduced and impacted food in diastemata should be removed. Diastemata can be mechanically widened (removing most dental tissue from the displaced tooth. Finally, displaced teeth can be extracted, especially when markedly displaced or rotated, and this procedure is most readily performed in older horses, especially when deep periodontal disease is present.

References


Acquired Disorders of Equine Teeth

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Introduction

Equine dental disorders are of major importance, with a British survey showing that 10% of equine practice time is spent on dental-related work. Likewise, a U.S. survey showed dental disorders to be the third most common equine medical problem encountered by large animal practitioners. Despite its importance, equine dentistry has until recently been a neglected area, with postmortem studies indicating up to 80% prevalence of undiagnosed, clinically significant dental disorders in equids. For example Honma et al. found that all horses > 12 years of age had dental caries; Baker found that 60% of horses > 15 years old had periodontal disease and 79% had infundibular caries. More recently, a high prevalence of dental disorders, and in particular CT diastemata, was demonstrated in aged donkeys in a postmortem survey with some associated with fatal colics.

Abnormalities of Wear

Normal tooth wear (attrition) occurs when the occlusal surfaces of opposing teeth come into occlusion and grind off each other. Any asymmetry in the position of the jaws (e.g. as occurs with developmental cranio-facial abnormalities) or of individual teeth (e.g. with hypodontia (too few), polyodontia (too many) or displacements will result in uneven dental wear. The periodontal membranes adjacent to overgrown teeth can become diseased, due to abnormal drifting of overgrown teeth causing diastemata. Additionally, the pain and possibly mechanical obstruction caused by dental overgrowths can restrict masticatory movements that in turn will restrict intra-oral saliva and food movements. This can lead to peripheral caries, periodontal disease and occasionally, local calculus formation.

Overgrowths can also cause soft tissue trauma which also can lead to clinical signs such as biting abnormalities in ridden horses and less commonly quidding.

Cheek Teeth Overgrowths (“Enamel Points”)

The presence of anisognathia (jaws of unequal widths) and also having maxillary cheek teeth (CT) that are wider than their mandibular counterparts contributes to the development of enamel overgrowths on the buccal aspect of the maxillary and lingual aspect of the mandibular CT in equids. These overgrowths lead to buccal mucosal ulceration (rarely to tongue ulceration) and in severe cases may cause biting problems and quidding. The lateral aspect of maxillary cheek teeth of some horses have very exaggerated vertical ridges (cingulae) that predispose to the development of focally sharp areas. Horses on a forage diet have wide masticatory movements in contrast to a predominantly vertical crushing stroke, when high levels of concentrates are fed.
that, along with the reduced amount of time spent masticating concentrates, promotes the development of CT enamel overgrowths and increased CT occlusal angles. However some horses that never receive concentrates will develop sharp maxillary cheek teeth overgrowths with buccal ulcers opposite the caudal maxillary teeth. Enamel overgrowths predominantly cause clinically significant disease in ridden horses, especially when associated with the use of tight nosebands. There is however still some debate on the need to remove tall and sharp overgrowths in horses without buccal ulceration and factual research is needed in this area.

Shear Mouth

If the above noted generalized CT overgrowths are not reduced by routine dental treatment, they may increase to such an extent that they interfere with the normal lateral masticatory action which further perpetuates overgrowths and may lead to a condition termed shear mouth in some horses. It was formerly believed that cheek teeth with occlusal angles of >15° could be termed shear mouth, but it is now accepted that the caudal mandibular teeth normally have angles of up to 30° and shear mouth represents much higher (>45°) occlusal angles. Horses affected with shear mouth have reduced effectiveness at grinding food on the affected side, especially when fed dried forage such as hay, and may later exhibit quidding, due to soft tissue injury and to the inevitable painful periodontal disease that accompanies this disorder.

Wave Mouth

Wave mouth is the presence of an undulating occlusal surface of the cheek teeth row in a rostro-caudal direction. Differential rate of CT eruption between opposing CT may be a cause of wave-mouth (that may even increase with time), as has the presence of large focal overgrowths (e.g. due to absence of or defective opposing teeth). Severe wave mouth can cause restricted mastication, and multiple concurrent dental (e.g. shear mouth or diastemata) and periodontal disorders will inevitably develop later.

Step Mouth

The loss of a cheek tooth can cause a rectangular shaped overgrowth, i.e. stepmouth due to increased eruption and absence of wear of the unopposed ipsilateral tooth. However, dental drift of the teeth adjacent to the extracted tooth may in time, cause the overgrowth to become more triangular in shape. Step mouth can also be caused by CT maleruptions, such as different rates of eruption of opposing CT, with the earliest erupted CT becoming and remaining overgrown (“dominant”). Less severe CT maleruptions may lead to wave mouth and there is often an overlap between these two disorders. These overgrowths can mechanically interfere with normal mastication leading to wavemouth or shear mouth.

The maxillary CT of older horses with worn infundibulae (especially the 09s that erupt first and also commonly have infundibular cemental hypoplasia), or maxillary CT with developmentally short infundibulae or with infundibular caries, have reduced enamel content and thus wear resistance that allows the opposite mandibular CT to overgrow. Likewise, older horses can have reduced peripheral enamel infolding of their mandibular CT and so will develop overgrowths of the opposite maxillary CT.
**Smooth Mouth**

In older equids the reduction and eventual loss of peripheral and infundibular enamel is a normal end-stage of dental attrition.\textsuperscript{17} This leads to the presence of a smooth occlusal surface containing predominantly cementum (due to increased deposition around the residual roots) and dentine, with minimal areas of protruding enamel. This condition is commonly termed smooth mouth. The residual dentine and cementum are no longer protected from normal attrition by the presence of adjacent (harder) enamel and such teeth are ineffective at grinding, and rapidly wear further.\textsuperscript{18} Smooth mouth can develop in younger dysplastic teeth where there is insufficient or poorly distributed enamel peripheral or infundibular enamel\textsuperscript{15} or enamel dysplasia.

**Diastemata**

As noted in the developmental disorder section, diastemata (a detectable interdental space between adjacent teeth) can be termed primary (developmental – inadequate compression) or secondary.\textsuperscript{19,20} Secondary diastemata can develop beside developmental or acquired displacements (usually medial (lingual) displacements of lower 10s and 11s), supernumerary cheek teeth or dental loss. Because equine CT slightly taper towards their apices and the angulated 06s, 10s and 11s lose their angulation with age, senile diastemata commonly develop between many CT in aged horses.

With marked food entrapment, the periodontal disease progresses to cause lysis and remodeling of alveolar bone and less commonly apical infection, osteomyelitis of the mandible or maxillae or oromaxillary fistula formation. Quidding is the most common clinical sign with CT diastemata, which is regarded as one of the most painful dental disorders of horses.\textsuperscript{15,19} Open mouth radiography can help assess the cause, severity and prognosis with CT diastemata.\textsuperscript{21} In younger horses with this disorder, further eruption of the CT and compression of the CT rows may even result in resolution of the diastemata, provided there is sufficient CT angulation.

**Disorders of Pulp**

**Pulpitis**

Because of the intimate relationship between dentine and pulp, these two tissues can be termed the dentino-pulp complex, which emphasises the fact that an insult to dentine can insult pulp and the reverse also holds true. In human teeth, pulpitis (inflammation of the pulp) occurs most commonly secondary to caries that has penetrated the enamel. Other potential causes of pulpitis in any species include pulpar exposure secondary to accidental or iatrogenic trauma (e.g. due to use of motorized dental equipment or dental shears).

The inflammatory response by pulp includes the development of pulpar oedema and the influx of inflammatory cells. Because pulp is encased in a rigid dentine chamber, such an inflammatory response increases pressure in the affected pulp that can collapse its vasculature. This can cause pulpar hypoxia that may lead to localised or generalized pulpar necrosis and death. However, equine teeth especially young teeth, have large apical foramina and a large blood supply to their pulp (which allow lifelong deposition of subocclusal dentine), and so equine teeth may resist a
degree of pulpar oedema and inflammation that would cause ischaemic pulpar death in brachydont teeth. If an exposed equine dental pulp survives the inevitable oedema, and also the invasion by oral bacteria, tertiary dentine formation will seal off the area of insulted pulp from the healthy underlying pulp and hopefully result in complete resolution of the pulpitis.  

Alternatively, if the pulp cannot seal off the insulted area, it may undergo necrosis or severe bacterial infection and spread to involve the full pulp including the common pulp chamber, and then extend to involve the periapical tissues leading to apical infection. If the pulpar death can be localized by the body’s defenses, the occlusal aspects of the pulp may die but the underlying pulp remains viable and may seal off the pulp horn at a lower level – giving clinical occlusal pulpar exposure that does not extend very deeply. This finding in multiple pulps of some teeth can occasionally be found in older horses and the cause of the pulpar insult is unknown.

Pulp Stones

Pulp stones, that more accurately should be termed false pulp stones, because they have no internal tubular structure have been observed in grossly healthy equine teeth, both within viable pulp (free stones) and in areas replaced with secondary dentine indicating that they do not usually compromise their pulp vitality.

Occlusal Pulpar Exposure

Odontoblasts that line the pulp cavity produce secondary dentine that gradually obliterates the pulp cavity circumferentially and subocclusally over the life of the tooth. In particular, subocclusal secondary dentine deposition (that is up to 100 times the rate of secondary dentine deposition on the pulp horn walls) prevents the pulp from becoming exposed on the occlusal surface in hypsodont teeth over the lifelong eruption of these teeth. This preferential subocclusal secondary dentine deposition is due to occlusal stimulation of the underlying odontoblasts. It was erroneously believed that an imbalance between occlusal wear and subocclusal secondary dentine deposition caused pulpar exposure on the occlusal surface, resulting in, descending infection and ultimately apical infection of the cheek teeth. However, more recent studies indicate that occlusal pulpar exposure does not occur in healthy equine CT, but is caused by prior pulpar damage that caused cessation or reduced deposition of sub-occlusal secondary dentine that eventually leads to occlusal pulpar exposure.

Cheek teeth pulpar exposure can be recognised clinically. Dacre et al. found occlusal pulpar exposure in 34% of apically infected mandibular CT and in 23% of apically infected maxillary CT, while van den Enden et al. found occlusal pulpar exposure in 32% of apically infected (maxillary and mandibular) cheek teeth, and also found occlusal pulpar exposure in 42% of CT with idiopathic fractures. Ultrastructural examinations of equine teeth have shown that exposed dentinal tubules can be present on the occlusal surface that may provide a potential route of infection of the pulp from the occlusal surface.

Multiple pulpar exposure (in single or multiple teeth) is occasionally seen in equid teeth (mainly in older animals) that have no evidence of apical infection and thus the presence of pulpar exposure does not necessarily indicate that pulpar or tooth death is present. Histological
examination of some equid CT with pulpar exposure has shown a layer of tertiary dentine protecting the pulp and sealing it off from an area of insulted pulp at the pulp horn occlusal tip that allowed (limited) pulpar exposure. However, especially in younger horses, the presence of multiple pulp horn exposure, of pulpar exposure with marked dentinal caries around the area of pulpar exposure, or of pulps that on probing are found to be deeply (>10mm) exposed, indicate the likelihood that the entire endodontic system has been severely damaged or is dead.

Apical Infections

Apical infection is a more accurate term to use in equids than “tooth root infection” because these infections often develop in young horses prior to any true root development, but they also occur in older CT with well developed roots. These infections are usually an extension of pulpar disease, as discussed earlier. Apical infections of incisor or canine teeth are rare in equids, but apical infections of CT are relatively common. CT apical infections are particularly significant in horses because of their great length, and consequently the infections usually spread to cause clinical changes in the alveoli and supporting bones. The clinical signs caused by CT apical infections depend on the site and age of the infected tooth, and the duration and the extent of the infection. When the rostral 2-3 maxillary CT are infected, rostral maxillary swellings and sinus tracts occur, with nasal discharge less common. Maxillary sinusitis is the main sequel when the caudal 3-4 maxillary cheek teeth are infected. Mandibular swellings and sinus tracts commonly occur with mandibular cheek teeth infections in younger horses. With older teeth, an apical infection may more readily drain via the periodontal membranes into the oral cavity and such case may just have halitosis as their only clinical sign.

As noted, occlusal pulpar exposure of CT is almost certainly a sequel to pulpar damage. The most commonly recognized cause of equine CT apical infection is anachoretic infection, i.e. blood or lymphatic borne bacterial infection (Figs. 1 & 2). Vertical impactions and hyperaemia of the developing apex can result in large eruption cysts (“3 and 4 year old bumps”) that in turn may predispose to anachoretic infections and this may explain the high prevalence of CT apical infections in younger horses.

Dental fractures are the second most common cause (20%) of apical cheek teeth infection (Figs. 1 & 2) and these fractures include gross, usually sagittal fractures and also hairline (fissure) fractures that communicate between the pulp and tooth periphery. Fissure fractures usually have dark staining (by bacterial or food pigments) on cut sections of extracted teeth. However, these fissures are not clinically obvious on the tooth surface unless the operator uses an oroscope or dental mirror and is aware of them. Not all idiopathic fractures (e.g. lateral slab fractures through the lateral pulp horns) cause apical infections as some such pulps can manage to seal off the exposed pulp laying down a layer of tertiary dentine to prevent infection spreading down the pulp horn.

Extension of infundibular caries to adjacent pulps is a specific disorder of maxillary CT that can cause apical infections (Fig. 2). Infundibular cemental hypoplasia (especially the 09s) with subsequent food impaction in the cemental defect predisposes to the development of infundibular cemental caries that may cause apical infections; either by weakening the tooth resulting in midline sagittal fractures; or by extension of the caries through the infundibular enamel into dentine and then pulp.
Figure 1. Routes of apical infection in equine mandibular cheek teeth.

Figure 2. Routes of apical infection in equine maxillary cheek teeth.
Apical infections can also occur secondary to developmental dental disorders (polyodontia, dental dysplasia, hypoplasia, diastemata and displacements), usually by an apical extension of periodontal disease (Figs. 1 & 2). As noted, periodontal disease can also be secondary to apical infections especially in older cheek teeth where exudate from the infected apex drains into the oral cavity via periodontal tracts – and thus avoids disease of the supporting bones (e.g. facial swellings or sinusitis).

**Dental Caries**

Caries is characterised by destruction of the calcified dental tissue with acid-producing bacteria the primary initiator of a chain of events. Bacterial fermentation of simple carbohydrates releases acids that decalcify the inorganic dental components (mainly calcium hydroxyapatite) at pH of 4 – 5.5. The most common type of dental caries identified in equine teeth is maxillary CT infundibular cemental caries. Honma et al. reported a prevalence of 100% in (maxillary) CT of horses over 12 years of age. Equine maxillary cheek teeth are predisposed to developing caries due to presence of developmental cemental hypoplasia of the infundibulum, often near the apical aspect of the infudibulum, that only become occlusally exposed with age. A recent study found that only 11% of infundibulae were completely filled with grossly normal cementum, and areas of cemental hypoplasia and cemental discoloration, respectively, were observed in 22% and 72% of infundibulae.

Cemental hypoplasia of the infundibulae of the rostral 3 cheek teeth can be due to premature destruction of the dental sac, such as by premature removal of overlying deciduous “caps”. However, recent examinations of CT of 1 – 3 years following eruption (dental age) showed a viable blood supply to the apex of infundibulae in many teeth. That would allow continued infundibular cemental deposition to occur for some years following eruption – but for some reason it is incomplete especially in the 09s. Marked infundibular cemental caries was found in 8% of infundibulae, with the Triadan 09 positions disproportionally accounting for 47% of these carious infundibulae.

Infundibular caries has been classified by Honma according to the extent of its spread into the different dental tissues. A modified classification of infundibular caries has been proposed by Dacre, which is also applicable for grading peripheral caries (Table 1).

Caries of the peripheral aspect of the equine teeth is increasingly recognized, but has been poorly described in the literature. Because it most obviously involves the peripheral cementum, it was termed peripheral cemental caries, which does not describe the full extent of this disorder that can also involve the underlying enamel and dentine. Peripheral dental caries may affect infolded peripheral cementum, including cementum that lies on the occlusal surface, and therefore can predispose to increased rate of occlusal wear and fracture of unsupported (hard but brittle) enamel. By causing destruction of the normal peripheral cement-periodontal attachments, peripheral caries can also initiate local periodontal disease. Infundibular caries can also extend through the infundibular enamel – even causing coalescence of both infundibula.

Severe peripheral dental caries involving all classes of teeth (incisors, canine and CT) have been found in some groups of horses fed high concentrate, low roughage diets, where the reduced time
spent masticating, high levels of fermentable simple carbohydrates and decreased volume of buffering saliva may predispose to prolonged periods of low oral cavity pH that causes demineralization of calcified dental tissue. Individual horses may be susceptible to this disorder. Peripheral caries is also concurrently found with other dental abnormalities, where restricted food and saliva movement may predispose to its development. Extensive generalised dental erosions has also been recorded in horses fed diets with a low pH, where excessive acids were added to silage (haylage) and in equids fed diets consisting largely of simple carbohydrates, i.e. processed maize foodstuffs. Unfortunately, there is minimal information on the bacteriology of the equine mouth in health or disease and this area that needs investigation.

Table 1. Modified Grading System for Equine Dental Caries

<table>
<thead>
<tr>
<th>Degree</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 degree</td>
<td>no macroscopic visible caries (can include infundibular hypoplasia)</td>
</tr>
<tr>
<td>1st degree</td>
<td>caries only affecting the cementum</td>
</tr>
<tr>
<td></td>
<td>from small pitting superficial spots (class 1)</td>
</tr>
<tr>
<td></td>
<td>extensive destruction and loss of cementum (class 2)</td>
</tr>
<tr>
<td>2nd degree</td>
<td>caries affecting cementum and adjacent enamel</td>
</tr>
<tr>
<td>3rd degree</td>
<td>caries affecting cementum, enamel and dentine</td>
</tr>
<tr>
<td>4th degree</td>
<td>caries now affects the integrity of the tooth i.e.</td>
</tr>
<tr>
<td></td>
<td>development of an apical abscess or secondary tooth fracture.</td>
</tr>
</tbody>
</table>

Dental Fractures

Traumatic Dental Fractures

Although incisors contain predominantly equine type-2 enamel that is relatively fracture resistant, traumatic dental fractures, particularly of the incisors, are relatively common in horses due to external trauma. In contrast, equine cheek teeth are composed of high levels of hard but brittle equine type-1 enamel, with even higher proportions of type 1 enamel in equine maxillary than mandibular cheek teeth. Nevertheless, traumatic equine fractures of equine CT are less common than incisor fractures due to their anatomical protection, with mandibular CT fractures due to external trauma and iatrogenic fractures (from use of dental shears) being common causes of CT fracture.

Idiopathic Cheek Teeth Fractures

The majority of equine CT fractures have no known history of trauma and consequently are classified as idiopathic CT fractures. Because maxillary midline sagittal fractures have been shown to be associated with advanced infundibular caries – these could now be re-classified. A
practice-based survey showed 0.4% of horses to be affected with idiopathic fractures.\textsuperscript{42} These fractures are often asymptomatic but can cause quidding and less often biting or behavioral problems, and halitosis.\textsuperscript{42,43} The upper 09s are most commonly involved and the predisposition of these teeth to infundibular caries is a likely factor for their midline sagittal fractures. The most common fracture pattern in idiopathic CT fractures are lateral “slab” fractures through the two lateral (buccal) pulp horns,\textsuperscript{41-43} possibly because the mineralised dental tissues are thinner at the sites of the pulp horns and therefore, the CT are weakest at this point\textsuperscript{77} (Figs. 3 & 4).

**Figure 3.** Common patterns of idiopathic mandibular cheek teeth fractures. R = rostral; C = caudal; B = buccal; L = lingual. The most common fracture pattern (red lines) runs through the two lateral pulp chambers on the lateral aspect of the tooth.

**Figure 4.** Common patterns of idiopathic maxillary cheek teeth fractures. R = rostral; C = caudal; B = buccal; L = lingual. The two most common fracture patterns run through the two lateral pulp chambers on the lateral aspect of the tooth (red lines) and through the infundibulae (green lines).

Examination of dentine showed thinner dentine in 25% of CT with idiopathic fractures, indicating prior pulpar disease, with the resultant thinner adjacent dentine mechanically predisposing to fracture. Dental pulps are inevitably involved in every (maxillary and mandibular) cheek teeth idiopathic fractures.\textsuperscript{41-43} Despite pulpar involvement, some idiopathic fractures (lateral slab fractures in particular), can clinically resolve without the development of clinical signs of apical infections, indicating that the resultant pulpitis has remained low grade or that the underlying pulp has become sealed off from the fracture site by the deposition of tertiary dentine. Many such fractured CT that survive following an idiopathic fracture have long-term radiographic apical changes, a subclinical endodontic and apical response to these CT fractures.

A proportion of fractured CT will develop pulpar infection that extends to clinically affect the apex, with the resultant clinical signs dependant on which tooth is involved. Clinical apical infection (including sinusitis) is common with maxillary midline sagittal fractures and with any type of mandibular CT fracture. Apically infected teeth always require extraction. In other affected teeth, mobile fracture fragments cause periodontal membrane stretching and pain during quidding until smaller dental fragments are spontaneously shed or extracted. Some fractured cheek teeth develop food impaction in the fracture site causing lateral or less commonly, medial
displacement of fracture fragments that causes soft tissue (usually buccal) ulceration and resultant quidding. Removal of the grossly displaced and/or of all mobile fracture segments is indicated. Prevention of dental fractures secondary to infundibular caries has been attempted by removal of carious infundibular cementum and filling the infundibular defect with endodontic restorative materials, but there is no objective research on the value of this treatment.

References

EOTRH: Macroscopical and Pathohistological Investigations

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Take Home Message

The etiological and predisposing factors of equine odontoclastic tooth resorption and hypercementosis (EOTRH) are not fully understood. However, pathohistological findings suggest an etiological contribution of biomechanical stresses.

Introduction

Painful incisor disorders have been increasingly recognized during the last several years preferentially affecting aged horses.1-3 Clinical examinations reveal oral/dental pain, incisor mobility, gingival swellings, severe gingival regression and gingivitis which are occasionally associated with ulcerations and draining tracks with purulent discharge.1,2

Radiographs display characteristic changes in the intraalveolar parts of the teeth and their periodontal surroundings, i.e. the periodontal ligament and the alveolar bone. Although the radiographic appearance varies between diseased teeth and between patients, there are two major radiographic findings which usually occur in combination.1,2,4,5 First, the intraalveolar parts of the teeth are affected by substantial tooth destruction in terms of resorption of the calcified dental tissues. Second, the intraalveolar parts of the teeth display bulbous enlargements caused by radiopaque masses. In addition, loss of the periodontal space, disaggregation of the alveolar bone and tooth fractures are frequent radiographic findings. Clinical reports indicate a progressive course of the disease with extraction of the affected teeth being the treatment of choice.

Hitherto, neither a comprehensive etiological and pathogenetic explanation for the described syndrome nor a tooth-preserving treatment has been presented. The purpose of the present study was to examine affected teeth in different stages of tooth resorption and hard substance hypertrophy to reveal the underlying pathological processes. The results might serve to identify etiological factors and also provide a basis for further studies addressing prophylactic procedures and tooth preserving therapies.

Materials and Methods

Macroscopical Examinations
Specimens were obtained from 53 horses with characteristic symptoms (46 geldings, 7 mares, ranging in age from 9 to 35 years, mean age 20 years).

Three hundred-twenty extracted teeth (297 incisors, 21 canines, 2 premolars) were cut into sections of approx. 10 mm in height using a diamond blade saw. Sectioned teeth were assessed using a dissection loupe (magnification 1.25-fold) to identify resorptive lesions, penetrations into the pulp cavity and presence of hypertrophic dental substances.

Histological Examinations

Selected specimens were decalcified using 25% EDTA at pH 7.4 and 37°C (requiring between two and four weeks). Subsequently specimens were embedded in paraffin wax and 3 micron serial sections were prepared. Alternate sections were grouped separately for different staining protocols (Masson-Goldner trichrome, picrosirius red, toluidine blue, haematoxylin eosin, tartrate resistant acid phosphatase [TRAP]) and microscopic procedures (light microscopy, polarized light microscopy). Examinations focused on the dental hard substances, the periodontal tissues and the dental pulp. Special attention was paid to detecting odontoclastic cells by means TRAP staining.

Results

Macroscopical Examinations

The intraalveolar part of the teeth featured characteristic appearances. A bulbous enlargement predominantly protruded in a lingual direction. The grossly irregular surface in such areas was suspected to be irregular dental cementum. The labial aspects of the teeth appeared unaffected with normal dental cementum. In some areas necrotic tissues was identified, especially in areas of irregular cemental deposition.

Sectioned surfaces in areas covered by normal cementum (labial aspects of the teeth) showed retained normal dental substances in most teeth. In areas covered with irregular cementum, the sectioned surface of the tooth often displayed a destroyed integrity of the tooth substances. Resorptive lesions extended beneath the normal peripheral cementum into enamel, dentine or even pulp.

Histological Examinations

Reflecting the macroscopical findings, two prominent histopathological findings were demonstrated, i.e. resorption of tooth substances and apposition of a calcified tissue. Tooth resorption was mediated by TRAP positive multinucleated odontoclasts. These cells were identified at the border of regular cementum and dentin lying in typical resorption lacunae (Howship’s lacunae). In areas where tooth resorption had ceased, cementoblast-like cells were found. These cells mediated the production of new calcified tissue, which was referred to as irregular cementum. The excessive apposition of irregular cementum causes the feature of hypercementotic enlargements of the tooth.
Accordingly the term EOTRH (Equine Odontoclastic Tooth Resorption and Hypercementosis) was proposed to describe the syndrome.

**Discussion**

The histological findings suggest a chronological sequence of tooth resorption which is followed by a reparative mechanism in terms of apposition of irregular cementum. This chronology of the cellular events is not synchronized along the entire tooth. Thus, sides of active resorption and sides of massive production of irregular cementum are in close vicinity to each other. The balance between simultaneous tooth resorption and apposition of irregular cementum defines the appearance of an affected tooth, and may favour a more resorptive type of EOTRH or a more hypercementotic type of EOTRH.

EOTRH shares many features with similar dental syndromes described in humans (multiple idiopathic root resorption, MIRR) and cats (feline odontoclastic root resorption, FORL). However, studies on these diseases have shown that the predominant pathological factor is tooth resorption which is followed by moderate production of reparative, cementum-like tissue as soon as the sustaining stimulus for tooth resorption has vanished. The dimensions of newly formed cementum-like tissue described in the horse exceed those described in other species by far. In contrast to MIRR and FORL, there is evidence that the periodontal ligament of the horse is capable of reattaching to particular areas of the repaired tooth surface. This observation underlines the high capacity of the equine periodontal ligament for remodelling and regeneration.

Experimental studies in rat and mouse models have shown that high pressure forces within the periodontal ligament cause micronecroses and subsequently induces the activation of clastic cells. These results lead to an etiological hypothesis of EORTH which proposes mechanical stresses within the periodontal ligament as the initiating factor of odontoclastic resorption.

Alternative etiological explanations, including ischemic necrosis, genetic linkage, systemic disorders such as Cushing’s syndrome, hypervitaminosis A, hypocalcaemia or hyperparathyroidism and idiopathic diseases, should be kept in consideration when performing further studies. Also a multifactorial genesis, including severe periodontal infections with particular pathogens, cannot be excluded.

**References**

Equine Odontoclastic Tooth Resorption and Hypercementosis: An In-Depth Evaluation of 15 Cases to Determine Any Possible Causes or Associations

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Take Home Message

This presentation is a preliminary evaluation of a research project involving 15 horses that have been diagnosed with Equine Odontoclastic Tooth Resorption and Hypercementosis Syndrome (EOTRH Syndrome). Broad evaluations of these cases have been conducted with 1) in depth medical history, 2) radiographic interpretation, 3) histopathology and 4) hematology. The goal of this pilot study is to identify parameters that may represent correlations and/or associations with this disease process.

Introduction

EOTRH syndrome is a painful condition of older horses (typically recognized at 15 years of age and older) that involves both the canine teeth and incisors. The lesions may penetrate into the dentin and eventually tract into the pulp. Equine resorptive lesions with hypercementosis involving the incisors and canines were first described in the horse in 2004 by David Klugh. The disease/syndrome was classified as periodontal disease involving the incisors and canines.¹ Robert Gregory published an article on this disease in 2006 and further described it as cemental hyperplasia and hypoplasia.² Robert Baratt accurately labeled these lesions as “resorptive lesions” in 2007.³ In 2008 this disease was described and classified by Carsten Staszyk as Equine Odontoclastic Tooth Resorption and Hypercementosis.⁴

Materials and Methods

This study involves 15 horses that have been diagnosed with the EOTRH Syndrome. The protocol of this project requires: 1) a complete history/physical exam, 2) radiographic evaluation and interpretation, 3) histopathological evaluation of an extracted tooth and 4) hematological evaluation of each patient.
The history and physical examination involves a questionnaire recorded by the submitting veterinarian. The questionnaire categorizes the patients by signalment (age, breed, sex etc.), type of diet, frequency and type of previous dental care, past drug usage (antibiotics, phenylbutazone, banamine etc.) and overall health of the horse (body conditioning score, body coat, T.P.R. etc.)

The radiographic images of the maxillary and mandibular incisor and canine teeth were submitted by the contributing veterinarians. The radiographs were evaluated for the stage of disease in the clinically affected teeth, the tissues involved, and radiographic evidence of disease in subclinical teeth. The evaluation of the radiographs was conducted independently by each author and then the findings were compared.

The histopathological evaluation was conducted by Dr. Rebecca Smedley. The pathological findings are structured into descriptive categories (cemental hyperplasia, cemental hypoplasia, resorptive lesions, bacteria present, dentinal lesions, endodontic/pulp lesions, etc.) The findings are compiled into a spreadsheet for comparative analysis. See abstract from Dr. Smedley titled “Equine Odontoclastic Tooth Resorption and Hypercementosis Syndrome in the United States”.

The hematology was conducted by the Diagnostic Center for Population and Animal Health at Michigan State University and includes: 1) Complete Blood Count with differential, 2) Chemistry Panel, 3) Cushing’s Panel (ACTH, Insulin, Glucose and Cortisol), 4) Thyroid Profile (TT4, TT3, FT4 and FT3), 5) Parathyroid Profile (Parathyroid Hormone, ionized calcium, Parathyroid Hormone related protein), 6) Vitamin A and 7) Vitamin D (25 Di-hydroxy). The data is compiled into a spreadsheet for analysis.

Results and Discussion

Preliminary results and discussion will be outlined during the presentation.

Conclusion

The scope of this pilot project for the EOTRH Syndrome is of a very broad perspective. The goal of the study is to identify and flag certain parameters that may be associated with the disease process. Negative findings are as important as positive findings. By design, the information gleaned from this pilot study will direct researchers toward larger, more “streamlined” projects which will improve our understanding of the EOTRH Syndrome.

References


Clinical Management of Equine Odontoclastic Tooth Resorption and Hypercementosis

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Clinical cases contributed by Lynn Caldwell, DVM; Edward T. Earley, DVM, FAVD; David L. Foster, VMD; Stephen S. Galloway, DVM, FAVD; Jon Gieche, DVM; and Carrie Niederman, VMD

Abbreviations:
- TR: tooth resorption
- EOTRH: equine odontoclastic tooth resorption and hypercementosis
- CRA: crown amputation
- PDL: periodontal ligament
- NSAID: nonsteroidal anti-inflammatory drug
- CRI: constant rate infusion

Introduction

Equine odontoclastic tooth resorption and hypercementosis (EOTRH) is a relatively recently described clinical syndrome in the horse.1-3 This syndrome is characterized by both tooth resorption and hypercementosis, and affects the incisors and canine teeth, generally in older horses. Tooth resorption (TR) frequently affects all of the incisors, with progression from the 3rd to 1st incisors over time. Incisors with early radiographic evidence of TR may have no associated clinical signs. Incisors with more advanced TR may have concomitant alveolar bone lysis, and fistulation through the attached gingiva or near the mucogingival junction overlying the affected tooth root. Spontaneous incisor or canine tooth fracture is often the first clinical sign noted by the owners. In some horses hypercementosis, as well as TR, is a prominent feature. These horses often have significant bulging of the incisive bone or the rostral mandibles associated with this incisor tooth root hypercementosis. While more advanced TR leads to mobility and fracture, the teeth with significant hypercementosis are generally immobile and not affected by fistulation. In some horses, the main clinical feature of EOTRH is vestibular extrusion of the affected incisors. The etiology of this syndrome has not yet been determined.

Initial efforts to treat this syndrome consisted of the combined use of corticosteroids and antibiotics.1,2 These treatments were found to be palliative, short lasting, and failed to arrest the progression of TR. Presently, management consists of extraction of affected incisors and canine teeth that are considered to be a cause of oral pain. This paper will briefly review the clinical manifestations of EOTRH and the surgical management of affected incisors and canine teeth.

Materials and Methods

Medical records of EOTRH cases from clinical practices in Connecticut (RMB), Pennsylvania (ETE), New Jersey (DLF), Texas (CN), Tennessee (SSG), Wisconsin (JG) and Oregon (LC) were collected. The diagnosis was based on radiographic evidence of tooth resorption and
hypercementosis in multiple incisors and/or canine teeth in adult horses greater than 15 years of age. Treatment consisted of extraction of severely affected teeth. The method of extraction, number of teeth extracted, use of a flap closure and postoperative complications and follow up findings were compared.

**Results**

The information for 22 horses with EOTRH that were treated by surgical extraction of one or more incisors or canine teeth is shown in Table 1. Horse #6 had surgical extractions on 3 different occasions over the period of 3 years. Horses #20 and 21 had all the maxillary incisors extracted in one procedure, followed by extraction of all the mandibular incisors at a later date. The average age was 22.4 years, with a median of 23 years, and all the patients were geldings. The most common breed was the Thoroughbred (9/22) but European warmblood breeds as a group predominated (10/22). The diagnosis of EOTRH was made on the basis of clinical signs and intraoral radiographs. The average number teeth extracted on a single occasion was 3.4, with a range of 1-12 and a median of 2. Horses #7 and 22 had crown amputation with intentional root retention of one and two canine teeth respectively.

A mucogingival flap closure of the extraction sites was attempted in approximately half of the cases. In instances where tension free closure was not possible, partial closure was performed or no attempt to close the extraction sites was made. Even with tension free flap closure, wound contracture with dehiscence was commonly reported, but with no apparent adverse effect on healing. While post-extraction radiographs were taken in all cases to insure extraction of the entire tooth root, long-term follow up was available for only 11 of the 25 surgical extraction procedures. Complications of surgical extraction of incisor teeth were infrequently reported. One horse (#18) that had undergone general anesthesia and surgical extraction of 3 incisors and 1 canine tooth, exhibited mild colic signs postoperatively, and responded to conservative therapy. Oral mucosal ulceration from sutures (2-0 polydioxanone) was observed on horse #7. All sutures were removed 7 days postoperatively and the oral ulcerations resolved with no further therapy. All horses had feed material adherent to the extraction socket and/or sutures until there was complete gingival healing. One horse (#8) exhibited decreased appetite for several days postoperatively, which the owner thought was due to oral pain. This horse was managed with 1 week of phenylbutazone (1 gm, BID).

**Discussion**

The early signs of EOTRH are subtle discoloration, edema and fistulation of the attached gingiva over the affected tooth root. Radiographic examination of horses with these earliest clinical signs usually revealed marked TR and/or hypercementosis, with the 3rd incisors usually showing more TR than the 1st or 2nd incisors. As TR progresses, spontaneous fracture of the affected incisor occurs, usually at or just apical to the free gingival margin. This is often the first clinical sign noted by the owner and is a frequent chief complaint. Incisors with significant TR are often slightly mobile and the horse will resent palpation or percussion of the tooth. The owner may report that the horse will no longer grasp a carrot with the incisor teeth. To date no cases of TR with hypercementosis have been reported that involve the cheek teeth.
Table 1. Twenty-Two Horses With EOTRH Treated by Surgical Extraction(s)

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While the canine teeth were frequently affected, sometimes before the disease was clinically apparent in the incisors, this tooth was more likely to undergo TR with bone replacement without hypercementosis. Spontaneous fracture of affected canine teeth with uncomplicated healing of the gingiva over the retained tooth root has been observed and was the rationale for performing crown amputation (CRA) and intentional root retention in two horses. While this approach was successful in the treatment of horse #7, a fistula associated with one of the two intentionally retained canine tooth roots in horse #22 was present at a 6 month follow up exam.

The area of greatest TR is often the middle 1/3 of the reserve crown/root. Although there may be a thickened PDL space in the radiographs, tooth mobility noted is often due to the loss of tooth
structure in the middle 1/3 rather than attachment loss. These incisors, if not fractured on presentation, are likely to fracture during extraction, leaving a tooth root that is difficult to elevate from the alveolus. Three methods have been used for the extraction of these retained incisor tooth roots. The first technique is the use of sharp luxators or flexible fine chisels to cut the PDL in a circumferential and apical manner. This is followed by standard elevation. The second technique is alveoplasty of the buccal (vestibular) bone plate using bone chisels, rongeurs or carbide burs on a high speed handpiece with water irrigation. With removal of the buccal bone and PDL, the root is more readily elevated from the socket. A third technique is to screw a positive thread Steinman pin into the retained root, and use the pin as a “handle” for putting traction on the root fragment while elevating it from the socket. Regardless of the technique used, post-extraction radiographs are necessary to confirm complete extraction of all dental fragments.

The extraction socket should be curetted to insure removal of all necrotic bone and inflammatory tissue. Sharp bony edges of the extraction socket should also be rounded with rongeurs and a bone rasp or a coarse diamond bur on a high-speed handpiece with water irrigation. With extraction of canine teeth and/or 3rd incisors, closure with a mucoperiosteal flap is not difficult. The design of the flap is largely personal preference, but the goal to achieve absolute tension free closure. The use of a releasing incision and/or severing the peristeam at the base of the flap is generally required. When the 1st and 2nd incisors are extracted advancement of a mucoperiosteal flap is more difficult and rapid wound contraction most likely will result in dehiscence. Partial closure with cruciate sutures may help stabilize the blood clot in the extraction site, but the sutures increase the adherence of feed material to the surgical site. At present, there is no evidence to support the use of materials to fill the extraction socket. Calcium sulfate (plaster of Paris, RMB), collagen impregnated with antibiotic (DLF) and polysiloxane dental impression material (ETE) and Consil (LC) were used on some of the cases in this study.

While difficult to assess in a retrospective study, the morbidity associated with multiple incisor extractions in cases of EOTRH was mild to moderate and required no more than nonsteroidal anti-inflammatory drug (NSAID) therapy. Extraction sockets heal quickly by second intention and are usually fully covered by healthy gingiva within 3 weeks. In those horses in which all the incisors are severely affected by TR and there is osteitis of the alveolar bone, some clinicians (DLF, LC) feel it makes more sense to remove all the incisors in one procedure rather than to stage the extractions in multiple procedures. This procedure was done on 3 of the horses (#16, 17 and 18) under general anesthesia, with 1-3 surgeons working at one time to complete the surgery in about 2½ hours. The remaining clinicians in this study performed the extractions in the sedated horse with regional nerve blocks and local infiltration of anesthetic. The maximum number of teeth extracted at one time in the standing horse was 6 incisors and one canine tooth (#20).

The regional nerve blocks used by clinicians in these cases were the combination of an infraorbital and local palatal infiltration for maxillary incisors and canine teeth and the mental nerve block with local infiltration for the mandibular incisors and canines. The technique for performing these nerve blocks has been described previously. Standing sedation was most often in the form of a detomidine constant rate infusion (CRI), to which butorphanol was sometimes added. The alpha agonist has a predictable diuretic effect. When procedures lasted over 1 hour,
intravenous administration of an isotonic fluid (such as Lactated Ringer’s Solution) at a rate of about 5 ml/kg/hour was administered via a jugular catheter.

Conclusions

EOTRH is a relatively uncommon form of periodontal disease affecting the incisors and canine teeth of older horses. There appears to be a breed (Thoroughbred, warmbloods) and sex (male) predilection, with onset of clinical signs in horses in their early twenties. At the time of diagnosis, there is often varying degrees of TR and hypercementosis affecting most if not all of the incisors and canine teeth. Spontaneous tooth fracture with retained tooth roots, osteomyelitis of alveolar bone with draining tracts in the attached gingiva, and extrusion with gingival recession are commonly observed clinical signs. The etiology is unknown. Treatment by staged extractions of the most severely affected teeth has been successfully used to manage these cases. Healing of incisor and canine tooth extraction sites appears to be rapid and uncomplicated, with little more morbidity observed when all the incisors of an arcade are extracted in one surgery versus staging the extractions over time. While crown amputation with intentional root retention can be elected, care must be taken to select teeth with no evidence of PDL space in the intraoral radiographs.

References and Footnote


aPDS II, 2-0. Ethicon, Inc. Somerville, NJ.
Equine Odontoclastic Tooth Resorption and Hypercementosis Syndrome in the United States

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Take Home Message

The histopathologic features of equine odontoclastic tooth resorption and hypercementosis syndrome in North American horses are similar to those previously described in European horses.1 In general, affected teeth exhibit moderate inflammation of the periodontal ligament and marked proliferation of irregular cementum with large scalloped lytic lesions often containing amorphous necrotic debris, bacteria and plant material. In some cases the irregular cementum and lytic lesions extend through the dentin into the pulp cavity. It is important to differentiate this syndrome from cementomas, which are benign tumors of cementoblast origin. The exact underlying etiology is still unknown. It is thought that odontoclastic activity results in resorptive lesions, which the cells of the periodontal ligament attempt to repair by marked production of irregular cementum.1

Introduction

Equine odontoclastic tooth resorption and hypercementosis (EOTRH) syndrome is a painful condition of older horses (15 years of age and older) that involves both the canine and incisor teeth.1,2 EOTRH is uncommonly recognized by veterinary pathologists and must be differentiated from a cementoma.3 The etiology is unknown. This syndrome has been described in Europe,1 the United States,2 and, most recently, Australia.4 The goals of this descriptive study were: 1) to classify the histopathologic features of EOTRH in 11 affected horses, ranging in age from 18 to 28 years, from the United States; 2) to compare the lesions to those described in European horses; 3) to identify any possible associations, or lack of associations, with specific hematological values; and 4) to increase awareness of this syndrome among equine practitioners and veterinary pathologists.

Materials and Methods

For each horse, a complete history/physical exam, radiographic evaluation, histopathologic evaluation, and hematological evaluation were performed. Histopathology submissions ranged from one affected tooth to the entire rostral mandible and maxilla. The samples were fixed in
10% neutral buffered formalin for at least 48 hours. Some teeth and jaw sections had been previously sectioned into multiple transverse sections and others were submitted whole. Large specimens were sectioned with a band saw to help speed decalcification. They were then placed in an overnight decalcification solution. The samples were checked daily to see if the tissues were soft enough to section. If they were not, the decalcification solution was changed, and the samples were assessed again the following day. This process was repeated until the specimens could easily be sectioned with a scalpel blade. In general, it usually took one to two weeks of decalcification before the samples could be sectioned, depending on the size of the specimen. Next, the samples were trimmed into 3 mm thick transverse sections and placed into cassettes. The cassettes were rinsed in running water for 2-4 hours and then placed back into 10% neutral buffered formalin for at least 48 hours before the cassettes were routinely processed, embedded, sectioned, and stained with hematoxylin and eosin (H&E). The histologic sections were routinely examined via light microscopy. The pathological findings were divided into descriptive categories (cemental hyperplasia, cemental hypoplasia, resorptive lesions, bacteria present, plant material present, dentinal lesions, pulp lesions, periodontal ligament lesions, and gingival lesions). Hematological evaluation included the following: 1) Complete blood count; 2) Chemistry panel; 3) Cushing’s panel (ACTH, insulin, glucose and cortisol); 4) Thyroid panel (TT4, TT3, FT4 and FT3); 5) Parathyroid panel (parathyroid hormone, ionized calcium, parathyroid hormone related protein); 6) Vitamin A serum level; and 7) Vitamin D serum level. This presentation will focus on the histopathologic findings in these 11 affected horses and comparison of the lesions to those described in European horses.

Results

Histologically, all horses had cemental lesions which included hyperplasia, proliferation of irregular cementum, and lytic lesions with necrotic debris; bacteria (7) and plant material (5) were noted in some. Periodontal ligament lesions, primarily inflammation, were noted in 10 horses. Gingival lesions were noted in 4 out of 7 horses that had gingiva present in the sections examined. All horses exhibited at least one dentinal lesion which included lysis (11) and necrotic debris (8). In one horse there was a large lytic area that extended from the cementum into the dentin that contained bacteria and plant material. Specimens from 10 of the 11 horses contained pulp cavity. All ten of these horses had at least one lesion in the pulp cavity which included inflammation (6), lysis (2), necrotic debris (2), fibrosis (8), and the presence of irregular cementum (8). In 2 of these 10 horses, a distinct pulp cavity was not seen due to a large lytic area that contained inflammatory cells, necrotic debris, bacteria, and plant material. Lesions in the alveolar bone were present in 4 out of 7 horses.

Investigation for associations with any of the hematological parameters examined in this study is in progress, and this portion of the study will be presented at a later date.

Discussion

In general, affected teeth exhibited moderate inflammation of the periodontal ligament and a proliferation of irregular cementum with large scalloped lytic lesions often containing amorphous necrotic debris, bacteria and plant material. In some cases the irregular cementum
and lytic lesions extended through the dentin into the pulp cavity. These histological findings are similar to those reported in Europe by Staszyk et al. and support the hypothesis that the syndrome is initiated by mechanical stress of the periodontal ligaments in older horses with shorter reserve crowns;\textsuperscript{1} however, the exact underlying etiology is still unknown. It is thought that odontoclastic activity results in resorptive lesions, which the cells of the periodontal ligament attempt to repair by marked production of irregular cementum.\textsuperscript{1} Both the pulp and the periodontal ligament of affected equine teeth appear to have the ability to initiate marked hypercementosis.\textsuperscript{1}

For suspected cases of EOTRH, extracted affected teeth should be placed in 10% neutral buffered formalin in a ratio of (tissue: fixative) 1:10 and submitted for histopathology. If post-mortem samples are obtained and the rostral mandible and/or maxilla are submitted, prior transverse sectioning of the jaw into approximately 2 cm sections improves fixation and speeds decalcification.

References


Acknowledgments

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How to Recognize and Clinically Manage Class 1 Malocclusions in the Horse

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Introduction

A malocclusion is defined as any deviation from normal occlusion. In the horse the normal occlusion (orthocclusion) is a level incisor bite. In man (and many breeds of dog and cat) the incisors have a scissor bite. The hypsodont dentition, angled conformation of the temporomandibular joints and anisognathism (mandibular jaw width narrower than the maxillary counterpart) result in the normal 10-15 degree angle to the occlusal surface of the cheek teeth and enamel points on the lingual aspect of the mandibular cheek teeth and buccal aspect of the maxillary cheek teeth. The normal horse has a curvature of the occlusal surfaces of the cheek teeth in the longitudinal plane, the curvature of Spee (Fig. 1). The rostral angulation of the distal cheek teeth and the caudal angulation of the mesial cheek teeth maintain tight interproximal contact until very late in life.

A class 1 malocclusion (neutoclusion) occurs in horses with normal jaw lengths and teeth in their normal mesiodistal location. Abnormalities of cheek tooth attrition are frequently seen and often described as waves, steps, hooks and ramps. While these types of occlusal abnormalities have not been previously classified as a type of malocclusion, their description as a class 1 malocclusion is justified and lends credence to the idea that occlusal adjustment is an orthodontic procedure. Similarly, abnormal incisor attrition or abrasion, given the descriptive terms smile, diagonal, stepped or irregular, and frown, can be considered another type of class 1 malocclusion.

A malpositioned tooth in the horse with normal jaw lengths, is another type of class 1 malocclusion. Rotations, embrications (crowding), displacements and versions (tilting) are seen in both the incisor and cheek teeth, with the highest incidence in the Miniature Horse. An overjet is a facial projection of the maxillary incisors, while an overbite is the vertical overlap of the maxillary incisors over the mandibular incisors. The overbite (parrot mouth), is most commonly seen in the class 2 malocclusion in which the mandible is short relative to the maxilla (Fig. 2). The maxillary incisor overbite or overjet (maxillary prognathism) may be accompanied by abnormalities in cheek tooth wear, such as hooks on the rostral maxillary and caudal mandibular cheek teeth. However, normal cheek tooth occlusion is often observed with these incisor malocclusions (Fig. 3). The class 3 malocclusion, in which the mandible is of greater length than the maxilla-incisive bones, is most commonly seen in the Miniature Horse. Mandibular incisor overjet or overbite (mandibular prognathism) may occur in the absence of cheek teeth abnormalities, but is most commonly associated with ramped mandibular 1st cheek teeth (306, 406).
The etiology of class 1 malocclusions generally can be determined by physical examination and radiographic imaging. Since malocclusions can be responsible for poor mastication, periodontal disease and poor athletic performance related to oral pain, proper diagnosis and management is important.

Figure 1. Quarter Horse gelding, 7-years-old. Normal development of sharp enamel points on the buccal side of the maxillary cheek teeth and the lingual aspect of the mandibular cheek teeth (left). Buccal mucosal lacerations (arrows). Normal curvature of Spee gives the false impression of a hook on the lower 3rd molars (311, 411). Conservative management: floating of the enamel points; note that very little rasping of the occlusal surface has occurred.

Figure 2. Quarter Horse mare, 11-years-old. Class 2 malocclusion (short mandible). Incisor overbite in conjunction with a normal cheek tooth occlusion.
Materials and Methods

The equipment needed and method of performing a thorough physical examination of the horse’s head and mouth has been described. The clinician should perform a brief physical examination prior to sedation, noting the horse’s body score, rectal temperature, and in some cases, observation of the horse’s chewing behavior and whether quidding is present. An extraoral examination should include the observation of any facial swelling, nasal discharge, malodorous breath, ocular discharge, ptyalism, painful response to palpation of the temporomandibular joint region, and lymphadenopathy. After sedation, and prior to placement of the full mouth speculum, oral examination of the lips, oral mucosa and gingiva of the lips and incisors, incisor malocclusions, periodontal disease and assessment of the lateral excursion to molar contact is performed. After placement of the full mouth speculum, the diastema between the incisors and the cheek teeth is examined and the presence of canine teeth and 1st premolars (wolf teeth) noted. The examination of the cheek teeth requires both an overall evaluation of the occlusion for patterns of abnormal tooth wear and a detailed tooth by tooth examination with a good headlight, dental mirror, dental explorer, and periodontal probe. Mobility of teeth can be assessed digitally and by using a variety of forceps. It is important to carefully examine the tooth opposite from any overly long tooth. While crown reduction of the overlong tooth may be indicated, the pathology is generally in the opposing tooth (Fig. 4).

The pulp horn numbering system devised by Dacre has been generally adopted. More recently, this numbering system has been modified by deToit. Particular attention to the presence of pulpar exposure in all cheek teeth is important. Any “catch” of the dental explorer on the occlusal aspect of a pulp horn should be noted. The depth of pulp horn and infundibular cavities can sometimes be assessed using 25-27 ga. hypodermic needles, but computed tomography studies have shown that these estimates generally underestimate the apical extent of the lesions. Recording of these findings on a dental chart is recommended and should be kept as part of the medicolegal records. Fewer errors and omissions will be made if an assistant records the findings that are dictated by the clinician as he performs the oral examination. The use of standard
abbreviations approved by the Academy of Veterinary Dentistry\textsuperscript{11} and the American Veterinary Dental College\textsuperscript{12} will facilitate communication with colleagues and specialists. Meticulous evaluation of any sites of feed impaction is important. A variety of instruments may be required to accomplish the removal of impacted feed material and cleansing and sounding of the diastemata and periodontal pockets. Long-handled straight and right-angled alligator forceps, long handled picks and scalers, marked (in millimeters) periodontal probes and irrigation devices are often needed. Accurate periodontal disease assessment requires the introduction of sharp instruments into the horse’s mouth, and therefore adequate sedation needs to be used to prevent iatrogenic injury to the oral soft tissues. Radiographic evaluation is certainly indicated when probing depths exceed 10 mm, there is significant tooth mobility or clinical evidence of apical infection.\textsuperscript{13} Techniques for obtaining diagnostic dental radiographs have been described.\textsuperscript{14} There have been several papers documenting the efficacy of widening the diastema between cheek teeth in cases where feed impaction is the cause of painful periodontal disease.\textsuperscript{15,16} Burs of various sizes and shapes are available from the manufacturer of some models of motorized dental floats.

Instrumentation for the reduction of tooth overgrowths is largely a matter of personal preference. While there is no substitute for direct visual oral examination, some practitioner’s prefer to use instruments (floats) to rasp tooth overgrowths with digital rather than visual guidance and assessment. In the author’s opinion, the use of motorized instrumentation allows easier direct visualization of the odontoplasty procedure and a more precise adjustment of occlusal abnormalities. The procedure is generally faster with motorized equipment and often the ergonomics are improved. A scanning electron microscopy study indicated that live odontoplastic processes were exposed by routine odontoplasty procedures, and that motorized floats resulted in less trauma to the treated surface of the tooth.\textsuperscript{17} Of course, the two types of instrumentation can be used in conjunction with each other. Regardless of the instrumentation used, care must be taken not to cause iatrogenic trauma to soft tissues or teeth. Removal of excessive tooth material can cause irreversible pulpitis either from direct pulp exposure or thermal damage.\textsuperscript{18,19} The clinician should always bear in mind that the equine hypsodont tooth is a vital structure, which continuously erupts. While removal of sharp enamel points on a young (less than 15-year-old) horse may be necessary at 6-12 month intervals, the older horse may require this only every 2 years or even less frequently. Tooth wear is also significantly affected by the horse’s access to pasture and the proportion of concentrate to roughage in the diet. Since an unopposed cheek tooth will erupt more quickly and has less wear than a normal cheek tooth, occlusal adjustment, in the form of crown height reduction, may be required at frequent (six month) intervals in a young horse and yearly in an older horse.

Once a diastema has formed between adjacent cheek teeth, an excessive transverse ridge tends to form on the opposing cheek tooth (Fig. 5). This dental overgrowth acts as a wedge, perpetuating or even increasing the diastema width.\textsuperscript{20} In some early cases, the associated feed packing and periodontitis may be adequately addressed by removal of the excessive transverse ridge/tooth overgrowth at shorter intervals (3-6 months) than the routine removal of sharp enamel points. Removal of the tooth overgrowth will often allow closure of the diastema (by mesial drift) and resolution of the periodontal disease. Similarly, a hook on the mesial aspect of the maxillary 2nd premolar will sometimes result in mesial orthodontic movement of this tooth that will correct
when the hook is removed. It is not possible to predict with any degree of certainty how much
tooth overgrowth can be removed without the risk of pulp exposure. Conservative odontoplasty,
the removal of less than 4 mm of clinical crown at any time, can be performed at 2 month
intervals when large tooth overgrowths must be corrected. The apical retraction of the vital pulp
and coronal deposition of secondary dentine in the pulp horns will occur in response to this
staged odontoplasty procedure. The coronal extent of the mesial pulp horn (#6) of the 1st
maxillary and mandibular cheek teeth is not likely to extend beyond the occlusal surface of the
body of the premolar. If the base of the hook is narrow, the entire hook can be removed at one
visit, as the #6 pulp horn is not at risk (Fig. 6). However, if the base of the hook is broader, a
more conservative crown reduction is justified (Fig. 7).

Figure 5. Quarter Horse gelding, 27-years-old. Wave complex with tooth overgrowth of 408 (left) and
excessive wear and diastema between 107 and 108, with food packing and periodontal disease (center).
Conservative odontoplasty of 408 (right) takes this tooth out of occlusion. In a younger horse this would
permit closure of the diastema and resolution of the periodontal disease. In this geriatric horse, the diastema
will persist, and reevaluation of the periodontal disease will be necessary to determine if further management
is needed.

Figure 6. Thoroughbred, mare, 11-years-old. The large hook, with a narrow base, was reduced in one session.
Once the cheek teeth overgrowths have been addressed, the full mouth speculum should be removed and the excursion to molar contact reassessed. If there is excessive excursion to molar contact, then conservative incisor crown reduction can be performed. Some diagonal incisor malocclusions have recently been shown to have accompanying deformation of the incisive bone. In the author’s opinion, it is not necessary and potentially deleterious (inadvertent pulp exposure) to perform occlusal adjustments of these cases in an effort to recreate a level bite. Odontoplasty of incisors is generally not required if there is normal excursion to molar contact (Fig. 8).

Figure 7. Quarter Horse gelding, 7-years-old. 106 hook with a broad base (left). Odontoplasty of about 5 mm (center). Further odontoplasty of about 5 mm the following year (right).

Figure 8. Arabian gelding, 20-years-old. Diagonal incisor malocclusion with normal cheek tooth occlusion and normal excursion to molar contact in both directions. This diagonal bite form of malocclusion has resulted in acquired skeletal deformation of the incisive bone and/or rostral mandible.

Results
Sharp enamel points are normal in the horse. While there is no doubt they are occasionally the cause of painful buccal or lingual lacerations in the horse, removal of enamel points (floating) has not been shown to affect either feed digestibility or performance in a limited number of studies.\(^{23,24}\) However, it is generally accepted that for many performance horses, the removal of sharp enamel points on the cheek teeth results in improved “rideability.” The author believes that this procedure should be conservative, and in general should not reduce the occlusal surface of the cheek tooth (Figs. 1 & 9).

Conservative management of class 1 malocclusions has, in the author’s experience, been successful in the vast majority of cases presented in general practice for a “routine float” (Fig. 10). With the exception of the geriatric patient, conservative management of diastema between cheek teeth is probably preferred over diastema widening, as the risk of iatrogenic pulp exposure is significant.\(^{25}\) Removal of the opposite tooth overgrowths and addressing any tooth overgrowths that are exerting orthodontic forces that tend to create the diastema should be attempted prior to diastema burring in most cases. In the author’s experience, mesial drift will often close the diastemata in horses less than 20 years of age, if tooth overgrowths are corrected.

Figure 9. Oldenberg gelding, 11 years old. Neutroclusion; sharp enamel points, buccal lacerations; before (left) and after (right) floating.

Figure 10. Thoroughbred gelding, 19 years old. Initial exam and odontoplasty of 411 step (upper left and right). Over the next 3 years the tooth overgrowths were addressed on 4 visits. The lower photos are the before (left) and after (right) on the occasion of the last odontoplasty, which returned the 411 to a nearly normal crown height.
Discussion

The hypsodont dentition of the horse is always in a state of eruption and wear. While class 1 malocclusions are commonly observed in the horse, the practitioner should bear in mind that the vast majority of these horses have an occlusion that is quite functional, with a normal excursion to molar contact. In these cases, the goal of intervention is to:

- Reduce dental overgrowths that are causing orthodontic movement of teeth, diastemata, feed packing and periodontal disease
- Reduce dental overgrowths that are the cause of traumatic soft tissue contacts or excessive wear of opposing diseased teeth.

With mesial drift and continued eruption of cheek teeth, conservative management of many class 1 malocclusions will be enough to eliminate the malocclusion in young horses with undamaged cheek teeth. The frequent occurrence of asynchronous eruption of the maxillary and mandibular 4th premolars is presumed to be a common etiology of the wave complex in which there is relative tooth overgrowth of the mandibular 4th premolars. In the horse less than 15 years of age, correction of this malocclusion may be possible with several crown reductions of 3-4 mm over the course of 1-2 years, as the short (infracluded) maxillary cheek tooth erupts without the occlusal contact of the opposite mandibular cheek tooth. On the other hand, in the older horse, there may not be significant reserve crown eruption of the infracluded maxillary cheek tooth to permit correction of the wave malocclusion. Again, very conservative odontoplasty is generally all that is required.

Complex malocclusions, such as waves, should not be corrected to a theoretical normal anatomical condition by trying to reduce the height of all overgrown teeth in an effort to create a “textbook” occlusion. This results in unnecessary removal of crown, runs the risk of iatrogenic irreversible pulpitis, would often require excessive incisor crown reduction to allow normal excursion to molar contact, and may result in quidding or even anorexia (Fig. 11). In the case of a mild to moderate wave, when the most overgrown tooth is opposed by a diseased tooth, then annual reduction of 3-5 mm of this “peak” of the wave is enough to keep the weakened tooth out of occlusion, and to protect it from traumatic contact. This degree of crown reduction is not associated with quidding or a measurable change in excursion to molar contact.
Another proposed etiology is the presence of infundibular cemental hypoplasia of the maxillary premolars or molars. This may predispose to infundibular caries, and a crown that is relatively weaker than the mandibular counterpart. Excessive wear is recognized as a prematurely expired (cupped) crown opposite the overgrown mandibular tooth. In this case regular reduction of the mandibular cheek tooth overgrowth will be required for the life of the horse.

Step overgrowths, ramps and large hooks on cheek teeth not only impede normal mastication, they exert orthodontic forces that move the overgrown teeth, with creation of diastemata. The resultant feed impaction in turn causes periodontal disease. Some hooks are so large that they cause significant trauma to the opposite soft tissues. In the author’s experience, removal of large hooks back to the level of the normal occlusal surface may need sequential reduction in order to avoid pulp exposure. Pulp exposure has been documented when removing the normal occlusal surface along the mesial aspect of the 2nd premolars (the so-called “bit seat”). Basic dental principles dictate that the occlusal tables should be preserved. In regards to large tooth overgrowths, until more scientific evidence is available, a conservative reduction of 3-4 mm every 2-3 months is recommended. The use of molar cutters is not recommended, as these instruments can cause vertical tooth fracture. In cases where the mandibular 3rd molar has a very large distal hook, a motorized float can be still be used by placing the instrument cutting disc on the lingual or buccal aspect of the tooth overgrowth and pressing it coronally until enough space is created so the float can be placed on top of the tooth overgrowth.

In the author’s opinion, if there is normal excursion to molar contact, then diagonal incisor bite malocclusions need not be corrected. In these instances, there has likely been adaptive remodeling of the incisive bone and/or rostral mandible (axial rotation and/or lateral deviation). Shortening of overgrown teeth will not change this skeletal adaptation. On the other hand, if incisor overgrowth has precluded molar contact, then crown reduction of the overlong incisors can be done in a conservative manner (3-4 mm, every 2 months).

References

Skeletal Abnormalities in the Equine Skull Associated with Diagonal Incisor Malocclusion

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Take Home Message

When evaluating a “Diagonal Incisor Malocclusion”, oral and radiographic examinations of the maxilla, mandibles, and dentition should be performed prior to treatment. Leveling of the incisors and symmetrical adjustment of the occlusal angles of the cheek teeth may not be indicated in an asymmetric skull.

Introduction

Traditionally Class I malocclusions in horses have been treated (crown reduction) without regard to the symmetry of the head and facial bones. In the 1890’s Edward H. Angle developed a classification system of malocclusion in humans which evaluated molar occlusion from a lateral profile (anterior-posterior plane). In the 1960’s Ackerman and Profit modified the Angle Classification System by additionally evaluating the incisors, crowding and asymmetry within the dental arches, and translation in three dimensional space (rostral/caudal, dorsal/ventral, and left/right). Currently, complete orthodontic evaluation also includes rotational evaluation about three perpendicular axes (pitch, roll, and yaw). In veterinary orthodontics this evaluation system has been adapted and is used for the classification of malocclusions in animals.

Materials and Methods

Horses with a diagonal incisor malocclusion were evaluated for skeletal abnormalities of the skull. Between 2006 and 2009, 42 horses with a diagonal incisor malocclusion were selected for oral and radiographic evaluations of the maxilla, mandibles and dentition for asymmetry.

Intraoral photographs were taken of the dentition and hard palate for observational evaluations and documentation. Examinations were performed for: 1) the direction of the incisor deviation relative to the maxilla, 2) hard palate yaw left or right, and 3) maxillary cheek teeth arcade (arch of the hard palate) roll in or out. Asymmetrical findings were documented in a spreadsheet. Symmetrical findings were scored as normal.

An extraoral dorsoventral radiograph was taken of each horse in the study. The radiographs were evaluated for skeletal asymmetry and abnormalities. The radiographic examination focused on yaw deviations of the: 1) Vomer bone, 2) Incisive bone, 3) Nasal process of the incisive bone and 4) Mandible body. The findings were documented in a spreadsheet. Symmetrical findings were scored as normal.
As a **control review**, ten horses with normal incisor occlusion were evaluated with intraoral photographs and an extraoral dorsoventral radiograph.

**Results**

Oral examinations of the hard palate demonstrated skull asymmetry in 41 of the 42 cases. Right maxilla deviations (28 cases) were more common than left maxilla deviations (14 cases). Hard palate *yaw* deviations were noted in 39 cases and hard palate *roll* deviations were noted in 41 cases.

Radiographic examination demonstrated skull asymmetry in all cases. The most consistent radiographic finding was a *yaw* deviation of the nasal process of the incisor bone (40/42). Vomer bone *yaw* was evident in 14 cases. Incisive bone *yaw* was evident in 22 cases. Slight *yaw* deviation of the mandible body was evident in 14 cases.

The control review revealed that slight observational asymmetry was evident in 2 of the 10 horses. All radiographic parameters were normal for the 10 control horses.

**Discussion**

An asymmetric arch of the hard palate was noted in 41 of 42 cases. The curvature of the palatal arch has a direct affect on the orientation of the cheek teeth within the quadrant. If the arch tends to “roll in” or steepen, the occlusal angle of the cheek teeth tends to increase. If the arch tends to “roll out” or flatten, the dental occlusal angle tends to flatten or decrease. In 33 of the 42 cases the palatal arch rolled in on the side opposite of the overall maxillary deviation.

The control portion of the study establishes that minor observational asymmetric parameters may be present with a “normal” incisor occlusion (2/10 – 20%). Radiographic controls revealed no asymmetrical findings (0% - 0/10).

The study group established an incidence of 97.6% (41/42) for observational asymmetry and an incidence of 100% (42/42) for radiographic asymmetry in horses with an incisor diagonal malocclusion.

An evaluation was made to determine if there was a correlation between the direction of the incisor diagonal and the occlusal angle of the cheek teeth. The incisor diagonal was described as an incisor bone deviation to the right or left. The occlusal angle of the cheek teeth was described as the arch of the hard palate rolling in or out. If the arch of the hard palate rolled in; the occlusal angles of the cheek teeth increased. If the arch of the hard palate rolled out; the occlusal angles of the cheek teeth tend to flatten or decrease. In 78.6% of the cases (33 of 42 cases) in this study, steeper occlusal angles of the cheek teeth were evident on the arcades opposite of the direction of the diagonal.

**Conclusion**
This study establishes an association between an asymmetrical skull and the diagonal incisor malocclusion. More research is needed to determine the effects of the asymmetric equine skull on malocclusion and masticatory forces. Currently there is minimal evidence to support traditional treatment modalities such as incisor leveling. Based on the findings of this study and the author’s experience, the most limiting factor for mastication in a horse with an incisor diagonal malocclusion is the malocclusion of the cheek teeth. Minor corrections and enamel point reductions of the cheek teeth will dramatically improve mastication.

References

Available upon request.
Pulp Happens – How to Perform Vital Pulp Therapy

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Introduction

Pulp exposures in horses can occur as a result of traumatic incident, abrasion or dental therapy. Though we should all strive to avoid accidental pulp exposure during dental treatments, the variable distance from occlusal surface to coronal pulp in the horse can make this challenging. Conservative reductions in crown height provide the best defense for iatrogenic pulp exposures. When pulp exposures do occur though there is a small window of opportunity to keep the tooth vital. Tooth vitality is essential to maximizing long-term tooth performance, as the tooth will be more resilient to occlusal forces and wear and less prone to resorption and apical infection. Maintaining vitality in young teeth is particularly important as it will allow the tooth to continue laying down dentin increasing its strength over time.

Two major types of dental fractures can occur. An uncomplicated crown fracture (T/FX/UCF) refers to loss of a portion of tooth involving cementum, enamel and/or dentin WITHOUT pulp exposure. These types of fractures can be either managed conservatively with no treatment, dentinal bonding, or restoration depending on the extent of the fracture. Complicated crown fracture (T/FX/CCF) refers to a fracture through the cementum, enamel, and dentin WITH pulp involvement and exposure. Treatment options for these fractures are extraction, root canal therapy, or vital pulp therapy depending on the timing and extent of the fracture. Pulp can also be exposed from rapid tooth wear called abrasion (AB). Abrasion is the pathologic wearing away of tooth structure by an external mechanical force (chewing on stall doors, trees, and watering systems, cribbing, iatrogenic reduction). If the rate of loss of dental structure exceeds the laying down of tertiary dentin, then a pulp exposure will result.

Research based guidelines for successful vital pulp therapy of human and canine teeth are well established. Research supported guidelines for vital pulp therapy in equine teeth have not yet been established though there are many anecdotal discussions and case reports of success using various techniques and timing in the literature. Though pulpal responses in horses have been shown to be more resilient than human and canine dentition, it is wise to adhere to the more conservative human/canine guidelines to maximize success of therapy. Teeth that are good candidates for vital pulp therapy are those <48 - 72 hours old and involve mostly the clinical and coronal reserve crown. Young teeth with large quantities of pulp have been shown to survive longer periods of exposure, up to one week, with no decrease in success rates. Performing vital pulp therapy past these timelines significantly reduces success rates in dogs and humans. Therefore, owners need to be informed of possible decreased success rates in horses if an extended or unknown period of time has elapsed between exposure and vital pulp therapy. Close radiographic follow-up of these teeth is also highly recommended (every 6 months).
Successful vital pulp therapy requires the adherence to three BASIC dental principles. These principles are: treatment of a non-inflamed pulp, application of a pulp dressing, and creation of a bacteria tight seal. To achieve these three goals of treatment one must remove inflamed pulp, apply an acceptable pulp dressing (calcium hydroxide or mineral trioxide aggregate), and create a bacteria tight seal with a high quality restoration. Vital pulp therapy has a high rate of success (95%) in humans and dogs if these principles are followed.

Four techniques have been described for treating exposed pulp: pulp capping, partial pulpotomy, full pulpotomy, and pulpectomy. Pulp capping is the direct application of a pulp dressing onto the exposed pulp with minimal restoration. These procedures are of marginal success and are currently not indicated for use in humans and dogs. Partial removal of coronal pulp is partial pulpotomy with restoration. This procedure is described below. Full pulpotomy refers to the removal of all coronal pulp to the level of the crown-root junction with restoration (not commonly indicated for use in the horse), and finally, a pulpectomy is the complete removal of all pulp tissue to the apical delta with subsequent root canal treatment.

**Pros and Cons**

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<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>Tooth remains vital and continues to mature and strengthen.</td>
<td>Repair may fail in future.</td>
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<td>Vital tooth responds to insult in more resilient manner than non-vital tooth.</td>
<td>Annual radiographic follow-up is recommended.</td>
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<td>Easier and quicker to perform than extraction or root canal therapy.</td>
<td>Procedure requires knowledge of basic endodontic and restorative principles.</td>
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<td>Fracture site in horse will wear away with age and tooth may appear normal in future.</td>
<td>Procedure requires materials and instrumentation not commonly carried by general practitioner.</td>
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<td>Relatively inexpensive.</td>
<td>Time limitations from exposure to repair must be respected to maximize success.</td>
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**Materials and Methods**

To maximize results the procedure needs to be performed in as STERILE a manner as possible. This means all equipment used to work with the pulp should be sterilized and only sterile saline should be used to irrigate the pulp during the pulpotomy (aka…turn off water from bulk tanks in high-speed dental units). Once a seal has been created over the pulp dressing, non-sterile instruments and techniques can be used.

Materials needed for pulp dressing:

- Ultrasonic scaler (optional)
**Antimicrobial irrigant (eg. 0.12% chlorhexidine solution in squirt bottle)**
**Polishing unit with prophy angle (optional)**
**Hand scaler and curettes**
**Fine diamond grit bur**
**Flour pumice in small dish (optional)**
**High-speed dental drill**
**Gauze**
**60ml syringe with large bore needle**
**bottle of sterile saline**
**Calcium hydroxide powder or Mineral Trioxide Aggregate (MTA)**
**Sterile X-Coarse paper points**
**Dycal:**
  - Jiffy tubes
  - Waxed paper pad – dental
  - Stainless steel dental spatula
**Light-cured or self-cured glass ionomer**
**Dental light-cure gun**

**Instruments to be kept in sterile tray for use:**

- Periodontal probe and explorer
- Surgical length 4 and 8 round carbide dental bur
- Surgical length cross-cut cylinder bur
- Amalgam carrier
- Stainless steel dental spatula
- Dental glass slab
- Metzenbaum scissors (small)
- College pliers unlocking
- Spoon excavators (various shapes and sizes)

**Materials needed for restoration:**

- 37% phosphoric acid
- Unfilled resin material (primer)
- Microhybrid composite material
- Plastic filling instrument
- Composite polishing paste
- White stone finishing bur

**Patient and Tooth Preparation:**

1. Adequately sedate patient, and place regional nerve block.
2. Take preoperative radiograph to evaluate if vital pulp therapy is appropriate.
3. Manage traumatized soft tissue surrounding exposed tooth if necessary.
4. Clean exposed crown of tooth to be managed.
a. Ultrasonic scaler and pumice polish work best for removing all organic debris from the crown surface. Remaining organic material on the crown surface can increase chance of pulp infection during procedure and decrease bonding of restorative materials.

b. If no ultrasonic equipment available, hand scalers/curettes and/or a very light touch with a fine diamond-grit columnar bur can be used for surface debridement.

5. Irrigate crown surface with antimicrobial flush. Place antimicrobial soaked gauze on the tooth for roughly five minutes to enhance site preparation.

6. Control regional soft tissue hemorrhage.

Sterile Partial Pulpotomy:

1. Put on sterile gloves and prep sterile tray.
2. Using sterile irrigation (assistant applies with syringe) and high-speed dental drill with cross-cut bur smooth tooth surface.
3. Using sterile irrigation and high-speed dental drill with either a 4 or 8 round bur remove exposed pulp to minimal depth of 7 mm.
   a. **Use of spoon excavators to remove inflamed pulp can result in partial or full avulsion of the pulp. Not recommended!**
4. Use college pliers to place sterile paper points onto remaining bleeding pulp. After initial wiping of access with paper points, place on pulp surface gently and leave in place till hemostasis achieved (3-5 minutes). A small amount of epinephrine (1 drop) can be placed into the access if bleeding is persistent.
   a. NEVER blow compressed air onto exposed pulp as air embolism may result.
5. Once the site is free of blood, the pulp dressing is prepared and applied. The pulp dressing should be roughly 1 to 2-mm thick. Either of the following two dressings work well. The sterile glass slab and spatula are used to mix either medicant. The author prefers MTA.
   a. Calcium hydroxide powder is mixed with sterile saline to create a dry paste. Practitioner uses amalgam carrier to deliver to pulp.
   b. MTA powder is mixed with premeasured saline (provided) to create a dry paste. Practitioner uses amalgam carrier to deliver to pulp.
6. Walls of access site cleaned with spoon excavators till no debris visible.
7. An intermediate layer is placed. The intermediate layer should be roughly 2-mm thick. A hard-setting calcium hydroxide cement (Dycal) or a glass ionomer can be used for this layer. Traditionally, Dycal has been used with calcium hydroxide powder and a glass ionomer has been used with MTA in veterinary applications.
   a. To use Dycal, mix even lines of base and catalyst on wax paper pad with spatula. Once uniformly mixed, scoop material into Jiffy tube, roll, and apply. This material will set in roughly 2 minutes.
   b. The type of intermediate glass ionomer purchased will determine manipulation. These materials will be light-cured, dual-cured, or self-cure. Follow package directions.

Final Restoration:
1. Now that the canal is sealed, work can continue in a non-sterile fashion. If composite is being used for final restoration, no undercut is necessary for cavity preparation.
2. Walls of the access site are cleaned with the spoon excavator. The walls must be pristine to maximize bonding of the final restorative materials.
3. Access walls are etched with 37% phosphoric acid for 15 seconds.
4. Rinse acid from tooth structure and catch on gauze for proper disposal.
5. Dry access site using compressed air source on dental unit.
6. Drop or brush a small amount of primer (unfilled resin) onto cavity walls. Use air to thin and coat walls of site. Cure with light-gun for 15 seconds.
7. Using plastic filling instrument place composite material into access site. Depth of composite should be a minimum of 3-mm to allow for best retention. Light-cure for minimum for 45 seconds.
8. Use white stone finishing bur or fine diamond grit bur to shape and smooth restoration.
9. Polish with composite polishing paste.
10. Take postoperative radiograph. This is a must for tracking and documenting response of tooth to therapy!

Follow-up:

1. Radiograph and visual exam at 6 months post-op followed by annual radiographic and visual exam.

Results

This author is unaware of any long-term clinical study investigating the optimal procedure for vital pulp therapy in the horse. Anecdotal evidence and clinical experience provided by multiple specialists demonstrates long-term successful outcomes for the procedure described.

Discussion

Access and visualization have always been an issue when treating teeth in horses. Vital pulp therapy can be treated with relative ease up to the level of the fourth premolar. Once to the level of the first molar, treatment becomes increasingly challenging; therefore, the practitioner should be very cautious with reduction of the molars and particularly the third molar tooth to avoid having to apply this technique in the back of the mouth.

Seven millimeters of pulpotomy is necessary for adequate vital pulp therapy. In humans, it is known that for 48 hours the pulpal response to exposure is proliferative extending 2-mm into the pulp. The longer a pulp remains exposed the more apical the inflammatory response proceeds. A minimum of 5-mm is necessary to provide adequate space for an intermediate and final restoration. Therefore, removal of a minimal 7-mm should be ample to provide 1-2-mm pulp dressing, 2-mm intermediate layer, and 3-mm final restoration. Performing a deep pulpotomy in a precise manner becomes more challenging after 7-mm as the surgical length dental burs do not extend much further without subsequent enlargement of the access site. It the author’s opinion, if greater than 7-mm of pulp needs to be removed to detect non-inflamed pulp then the practitioner should rethink his/her approach.
Just because a pulp bleeds does not mean it is healthy and capable of surviving long-term with vital pulp therapy. Some authors have reported using the quantity of blood produced following pulpal irritation with a file as a determining factor in treatment decisions. This is an extremely subjective test that requires an experienced eye to determine the “lack of” or “excessive response” in bleeding to pulpal stimulation. Sticking to established timing guidelines for vital pulp therapy will ensure greater success for the patient.

An ideal pulp dressing should stimulate healing of pulp tissue and formation of reparative dentin while being non-toxic, non-carcinogenic, biocompatible, insoluble in tissue fluids, antibacterial, antifungal and dimensionally stable. The two main choices for pulp dressing are calcium hydroxide powder and MTA. Calcium hydroxide has a long track record of successful usage for vital pulp therapy though it does not meet all ideal requirements. Its advantages are that it is antibacterial and antifungal disinfecting the superficial pulp. Due to its extreme alkalinity (pH=12.5), it will cause roughly 1.5-mm of pulp necrosis upon placement. This could be considered beneficial as it allows for additional debridement of inflamed pulp tissue. The toxicity of calcium hydroxide dissipates with depth and only mild inflammation will be present below the region of tissue necrosis. This mild inflammation will initiate hard tissue healing (tertiary dentin formation) in the absence of bacteria.

Mineral trioxide aggregate (MTA) is composed mainly of calcium, silica, and bismuth. It is also available in bulk as Portland cement. This material was developed to meet most of the ideal characteristics stated above. It is made of hydrophilic fine particles that harden in the presence of dampness or blood. It too has a high alkalinity that is regionally antimicrobial, but upon setting the material neutralizes and becomes biocompatible. It is radiopaque and it is harder to infiltrate than hard-setting calcium hydroxide cements. In addition, when dry, MTA has excellent sealing capacities. It requires a working time of about 5 min and a hardening time that varies from 3 to 6 hrs according to the density of the air entrapped during mixing and the dampness of the receiving site. The extended setting time can be considered a disadvantage. An extensive literature review demonstrates that MTA is a material of choice for pulp-capping in addition to many other endodontic applications.

There has been some discussion in the past as to whether the pulp can be treated as previously outlined with only a hard-setting calcium hydroxide cement (Dycal) for the pulp dressing, restoration and bacteria tight seal. Dycal is considered a low-strength base in human dental textbooks. It is used for direct and indirect pulp capping under stronger restorations and as a protective barrier beneath composite restorations. The physical properties of this low-strength base do NOT make it a good candidate for long-term restoration.

In conclusion, vital pulp therapy can be a successful treatment for acute pulp exposure in the horse by applying well-established dental principles.

References


Deciduous Tooth Management

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Take Home Message

Horses shed 24 deciduous teeth and erupt 36-44 permanent teeth between 1 and 6 years of age. This process should be monitored and interceptive care may be necessary to avoid problems with gingivitis and dental malocclusion.

Introduction

Knowledge of eruption times of deciduous and permanent dentition should be second nature to veterinarians working in the equine mouth. The shedding of deciduous teeth is an entirely natural process that generally does not require human intervention to proceed normally. It is not unusual for horsemen to report finding a deciduous tooth or tooth fragment in the feed trough or manure pile. As with other routine prophylactic procedures, however, the use of the horse as a ridden performance animal demands a mouth that is free of any source of possible discomfort. Therefore extraction of “caps” that are felt to be loose or close to exfoliation and causing gingival irritation is common practice when performing routine dental examination and odontoplasty in young horses.1,2 There are times when maleruptition of permanent teeth occurs which can lead to pathological retention of deciduous teeth.3,4 Interceptive orthodontics is the branch of dentistry that deals with retained deciduous teeth and their associated malocclusions.5

Tooth Eruption

Horses under five years of age have mixed hypsodont dentition. From 12 months to 6 years, equids shed 24 deciduous teeth and erupt 36-44 permanent teeth. Horses have vertically successional teeth, with each deciduous tooth and its underlying permanent tooth residing in the same alveolar crypt. Eruption is the process whereby a developing tooth moves through the supporting bone and into its functional position in the oral cavity, with emergence being the actual appearance of the tooth in the oral cavity. The functional crown will not be in wear for some weeks or months after tooth emergence and will be continually changing throughout the life of the tooth. The mechanisms of eruption of equine dentition have not been studied in detail. However, it is likely that, as in other species, the process is multifactorial with eruptive (from the periodontal ligament), resorptive and hydrostatic forces playing a role.6 The soft tissue layer between the permanent and deciduous tooth contains inflammatory and osteoprogenator cells, cytokines and odontoclasts that remodel the alveolar bone and resorb the apical portion of the deciduous tooth. Deciduous hypsodont crowns wear at approximately 3-7 mm per year. The combined action of resorption of the roots of the deciduous tooth, development and eruption of
the permanent successor and attrition of the clinical crown results in the shedding or exfoliation of a wafer of the deciduous tooth often referred to as a ‘cap’. The deciduous 1st incisors erupt at about 6 days of age, the 2nd incisors at about 6 weeks, and the deciduous 3rd incisors at about 9 months. Deciduous incisors are dome-shaped and smaller than the permanent incisors. They have a flattened root, short crown, and shallow infundibulum on the occlusal surface. The central incisor caps normally shed first (01s) at about 2½ years (30-34 months), the middle incisors (02s) at about 3½ years (40-44 months), and the lateral incisors 03s at about 4½ years (54-60 months). Miniature horses and ponies may not erupt permanent incisors for 6-18 months later than Thoroughbred horses. The eruption times of the deciduous and permanent incisors can be used to help estimate age.7,8

As the permanent incisor erupts, the deciduous tooth root is resorbed. Permanent incisors often erupt palatal or lingual to the deciduous tooth. Therefore, the incisor cap often retains the more labial portion of the root and sometimes displaces slightly rostral in the socket as it is shed.

In foals, the deciduous premolars erupt through the gingiva shortly after birth. The deciduous premolars undergo distinct root formation and have a much shorter reserve crown than the permanent premolars. It is of clinical interest that the clinical or exposed crowns of deciduous premolars resemble those of the permanent teeth. As the juvenile horse matures, the crowns of deciduous premolars wear thin and the roots resorb forming a flat premolar cap as the underlying permanent teeth erupt.

The sequence of eruption of permanent cheek teeth has been widely reported in the literature with emergence times of 1 year for M1 (09s) 2 years for M2 (10s) 2½ years for PM2 (06s), 3 years for PM3 (07s), 3½ years for M3 (11s) and 4 years for PM4 (08s).9

Recent work has shed new light on premolar eruption times in the Thoroughbred horse. In this proposed model, male horses compared to females had a younger age of permanent premolar tooth emergence by 38 days. The 106 and 206 have an older age of emergence by 14 days (age 35.1 months) compared with the corresponding teeth in the lower jaw (306 and 406). The typical 07 permanent tooth emerged about 96 days after the adjacent 06 (age 37.8 months) and the typical permanent 08s emerged at about 264 days later (43.3 months).10

Eruption pseudocysts are bony enlargements that can be observed in juvenile horses on the ventral aspect of the mandible and on the dorsolateral aspect of the maxilla. These pseudocysts normally result from erupting permanent premolars and are most prominent in 3-4 year-old horses. The pseudocysts and associated bony enlargements regress over a 1-2 year period. In general, eruption pseudocysts are not as noticeable on the maxilla because of the overlying soft tissue.

**Maleruption**

Worn crowns of the deciduous teeth (caps) become loose and subsequently either become displaced or are shed into the mouth. This is often associated with some degree of transient gingivitis and periodontal disease.
In horses with retained deciduous incisors, one or more teeth may fail to shed as the permanent teeth erupt. Incomplete cap shedding with retained tooth fragments can be a chronic source of gingival irritation. Discomfort may occur resulting in clinical signs such as head tossing during eating, rubbing the incisors on fixed objects, quidding, and bitting problems. Failure of a deciduous incisor tooth to shed is usually caused by the permanent tooth erupting slightly lingual to the deciduous, resulting in failure of the deciduous root to completely resorb. Permanent incisor teeth may also erupt at strange angles or positions which will also result in retention of the deciduous tooth. A narrow diastema may develop between the retained deciduous and erupted permanent tooth leading to periodontitis. Some cases of retained deciduous incisors may require a radiograph to differentiate this condition from a case of supernumerary permanent teeth.

Premolar caps can appear much like a table with four legs lying over the top of the permanent tooth. These wafer-thin portions of deciduous teeth (caps) can have a variable number of tooth fragments. Chronic gingivitis and periodontal disease can result if these root slivers are broken off and remain in the subgingival space after the cap is shed. The eruption sequence and tooth angulation of permanent molarized dentition predisposes to entrapment by blocking the eruption pathway of teeth in the permanent 07 and 08 column. Delayed shedding of deciduous premolars can predispose to gingivitis and periodontal disease. Gingival irritation secondary to retained, split, or displaced deciduous premolars can be distracting to the training process of a young horse. Additionally, retained deciduous premolars may cause dysmastication, anorexia, and predispose to malocclusion and abnormal crown wear of the permanent teeth. Trapped caps, manifested as bony enlargements or eruption bumps on the ventral mandibular ramus or maxilla rostral to the facial crest, can result from displacement or delay eruption of permanent teeth. These facial bony enlargements are only cosmetic problems in most cases. However, they can become pathological if eruption is severely inhibited or blood-borne bacteria inhabit the inflamed or ischemic dental pulp. This can lead to anachoretic pulpitis and facial swelling with a draining tract on the mandible or maxilla.

The equine teeth in each arcade are in tight apposition and act as a single grinding unit. It is easy to see how maleruption or displacement of a tooth can result in loss of integrity of an arcade. Typically, the permanent incisors erupt slightly lingual to the deciduous tooth while the permanent premolars usually come in squarely beneath the permanent. This process can be complicated when the eruption pathway of the permanent tooth is malaligned or impeded.

Conditions such as permanent tooth displacement, diastema formation and dental impactions are often attributed to disorders of tooth eruption. This would predispose to abnormal crown wear and periodontal disease.

Despite the lack of evidence based research into the etiology of patterns of malocclusions in the horse, it is common to encounter statements concerning the proposed premature removal of deciduous premolars to prevent dental block and permanent tooth displacement in certain circumstances, particularly in relation to PM4. Some practitioners have expressed concern about early or delayed eruption of permanent teeth playing a role in the formation of certain abnormal
dental wear patterns noted later in life such as wave mouth (i.e. dominant maxillary 10s, lower 08-09 wave, incisor smile or frown).

In some cases, crowding and compression (block) of the erupting permanent tooth may cause an unusually large, warm, painful swelling of the maxilla or mandible. If this should develop, an abnormally erupting or retained deciduous premolar should be suspected. Radiology should be used to evaluate the dental and bone structures associated with large eruption pseudocysts. On radiography, eruption pseudocysts of the mandible appear as smooth-bordered, periapical lucencies with sclerotic margins. It is important to remember that blood borne bacteria may invade inflamed dental tissue associated with eruption pseudocysts resulting in infection of the pulp and the periapical region through a process called anachoresis.

Deciduous premolar caps that are loose or fractured or ones that fail to shed properly, can irritate a young horse’s mouth. Clinical signs of discomfort include loss of appetite, head shaking and biting and chewing problems.

**Diagnosis and Treatment**

Digital and visual examination of the oral cavity prior to performing any rasping of enamel points will usually detect loose or displaced incisor or premolar caps or cap fragments. The presence of an obvious step in the occlusal plane of any cheek tooth arcade, resulting from whole or subtotal loss of a deciduous premolar, should prompt a closer examination of the corresponding tooth in other arcades. Deciduous premolar caps close to natural exfoliation should: 1) be digitally loose, 2) have partial loss of the crown, or 3) have a palpable demarcation noted on the occlusal and/or palatal aspect of the clinical crown with little or no gingival attachment to the remainder of the cap. Often malodor at the local site accompanies these findings.

Asynchronous eruption of analogously positioned permanent teeth is common in all species. As a general rule in equine practice, if one cap has shed, the cap in the same position on the opposite side of the jaw should be evaluated and, if loose or close to exfoliation, it should be removed. Otherwise the cap should not be extracted.

Retained deciduous incisor teeth may be a source of discomfort or cause dental crowding in the 3-6 year-old horse. Loose incisor caps are easily removed with small extraction forceps after minimal gingival elevation. Retained root or tooth slivers may need to be removed after sedation and local infiltration anesthesia with a root elevator and bone ronguer. Retained and displaced deciduous incisors may appear as a double tooth or arch of teeth. This may make it difficult to differentiate from supernumerary permanent teeth. Close evaluation of the occlusal surface is helpful to separate the newly erupted teeth with deep infundibulae from worn deciduous crowns. Radiographs are helpful in some cases. Uneven eruption of permanent incisors has been reported to be a predisposing factor in incisor malalignment and uneven wear (i.e. smile bite). Premature extraction, bone or dental fracture or deciduous dental avulsion has resulted in maleruption, malformation or failure of eruption of the permanent dentition.
In most cases the retained incisor cap and tooth remnants can easily be removed in the standing sedated horse. Local infiltration anesthesia should be used in most cases. A mental or infraorbital regional nerve block would only be necessary if long root fragments required a bone flap for elevation. A small root elevator and dental forceps is usually sufficient to loosen and extract the deciduous tooth. Root fragments should not be left as these can lead to chronic irritation and pain. Surgical removal through small gingival flap to expose a portion of the root is often less traumatic and may be indicated.

Deciduous premolar caps can safely be extracted when a line of demarcation is visible between the cap and the erupting permanent tooth. Because the crown of deciduous premolar teeth closely resembles the crown of a permanent tooth, it may be difficult to determine whether a premolar cap has been shed. The occlusal surface of newly erupted upper premolar teeth contains two deep infundibular cups. These teeth are usually in various stages of early wear and with close observation can be differentiated from a severely worn deciduous premolar. An open mouth lateral oblique radiograph can be helpful in determining if a cap is present. The premolar caps can be identified on a radiograph as a short, thin slice of tooth situated over the underlying permanent premolar.

The practice of methodically removing deciduous teeth at set ages results in the premature removal in some horses. The fleshy dental sac covering the underlying developing permanent tooth is exposed and quickly destroyed by mastication after the cap is removed. This leads to loss of blood supply to the occlusal aspect of the infundibulum, where active cement deposition may still be occurring. This may result in central infundibular cement hypoplasia and so predispose to the development of infundibular caries later in life.9

In the case of loose premolar caps found on manual examination, extraction is often performed digitally. In other cases, the remaining deciduous crown can be grasped with a cap extraction forceps and an attempt made to roll the cap off, usually in a palatal or lingual direction. Excessive force and multiple attempts should be avoided. If there is insufficient movement when the deciduous crown is grasped and manipulated with the forceps, the tooth should be considered not ready for exfoliation. Extraction should be abandoned in such a case.11

Management of displaced or teeth with blocked eruption secondary to or associated with retained deciduous teeth has been dealt with to a limited extent in the literature.3,4

References and Suggested Reading

Equine Oral Extractions

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Take Home Message

Exodontia should not be performed unless it has been determined beyond a doubt which tooth or teeth are problematic and all methods of medical, periodontic or endodontic therapy have been exhausted to arrest the disease process and preserve the tooth. The objective of exodontia should be to carefully plan and execute the extraction while protecting the alveolus and other oral tissues, thereby minimizing complications.

Introduction

Tooth removal should be a last resort after other methods to manage the diseased tooth or dental related problems have failed. Throughout the 20th century, exodontia has classically been the backbone of equine oral surgery.1 There are a wide range of indications for tooth removal, most of which depend upon which tooth or teeth in the arcade are causing a problem. Some common indications for tooth removal are associated with one of the following:

1. Interceptive orthodontics secondary to retained deciduous teeth
2. Periodontal disease secondary to diastema, dental maleruptions and displacements, supernumerary teeth and malocclusion
3. Endodontic disease or apical infection usually associated with secondary osteomyelitis
4. Surgical consideration in oral bone fractures
5. Disease or fracture to the dental crown or root
6. Occlusal trauma
7. Neoplasia
8. Bitting discomfort
9. Paranasal sinus disease secondary to oral or dental disease

Extraction can be simple or very time consuming. It can also be frustrating and fraught with operative and postoperative complications. The specific tooth involved, dental disease process, age of animal and number of teeth to be removed dictate the surgical technique employed and instruments utilized.2-6 Thorough treatment planning prior to beginning an extraction procedure will produce realistic expectations and minimize complications.

The earliest known method to remove diseased cheek teeth in the horse was via the oral route. This method has been practiced by veterinary surgeons for centuries on severely diseased or loose teeth. Molar extraction forceps have been available for well over 100 years and until very recently have changed little in design. In the mid-twentieth century with the advent of equine general inhalation anesthesia which makes working in the mouth around a mask or endotracheal
tube difficult, oral extraction lost popularity. For over 50 years, most equine teeth were removed surgically by trephination and retrograde repulsion. Most twentieth century veterinary literature limited oral tooth extraction to teeth that were loose or in older horses with short dental crowns. But in recent years modern sedative analgesic combinations and regional dental anesthesia have allowed veterinarians to safely access the standing horse’s mouth. This has lead to the development of better oral extraction techniques and manufacturing of a wide variety of high quality equine dental instruments.

Oral tooth extraction should be the primary method of tooth removal employed by the veterinarian. Even though a retrograde approach to the sinus or periradicular area may be necessary to reach an existing secondary disease condition, oral extraction should be attempted first. Proper extraction technique based on sound dental surgical principles minimizes postoperative discomfort and encourages rapid healing of associated soft tissues.

The basic principles of tooth removal in humans and small animals involve obtaining adequate access to the periodontium for tooth loosening, creating an unimpeded pathway for removal of the tooth and using controlled force to elevate the tooth without damaging adjacent structures. The interdigitating contours of the long reserve crown and presence of multiple roots on each tooth can make loosening and elevation of the equine tooth more challenging.

Oral extraction can be performed on any tooth but several dental disease processes require special consideration when planning surgery. Teeth with gross pulp horn or infundibular caries have crowns that may disintegrate during extraction. Diseased caudal maxillary teeth often are associated with secondary sinusitis and surgical drainage of the sinuses is required in this situation. The more caudally situated teeth are more difficult to access through the mouth making instrument placement and maneuvering more challenging. In aged animals with short reserved crowns or in the case of advanced periodontal disease that has resulted in loosening of the tooth, extraction may be carried out digitally. In young horses with apically diseased teeth and long reserved crowns firmly attached in the alveolus, extraction will require more effort and expertise. It may be necessary in some juvenile horses to remove permanent dentition prior to eruption which will complicate an oral approach. Young animals with long reserved crowns may present an insurmountable challenge to oral extraction. Extraction procedures range from minor to major surgical procedures and practitioners should critically evaluate their ability (training, experience, instrumentation, etc) before performing an exodontic procedure.

**Extraction Procedure**

**Incisors**

Most incisor extractions can be performed on the standing horse with proper chemical and physical restraint and local or regional anesthesia. Preoperative examination and when indicated, radiographs will define the type of pathology, tooth position and mobility index. Surgical technique can involve a simple gingival elevation and forceps extraction of a loose deciduous tooth or a chronically infected mobile permanent tooth. Solid incisors, whether deciduous or permanent with long reserve crowns, often require a mucoperiosteal flap and complete or partial removal of the labial alveolar plate of bone to be able to safely loosen and
elevate the tooth from its socket. Several surgical techniques are described in the literature.\textsuperscript{2,3,5} They require special instruments and expertise to achieve a healthy cosmetic result. Many times, these teeth are mistakenly only partially removed leading to continued periapical disease and future surgery. Because of the high potential for complications, referral of these cases to an experienced dental surgeon is often indicated.

**Cheek Teeth**

Careful preoperative examination of the patient is important, and all aspects of the approach to therapy should be planned before surgery is undertaken on cheek teeth. Special consideration should be given to the age of the horse, type of dental pathology, position and number of root apices, and the structural integrity of the tooth crown. Apically infected cheek teeth in young horses require more surgical support and instrumentation than most practitioners have at their disposal. Referral to an experienced dental surgeon may be in the best interest of the horse and its owner. Radiographic and endoscopic examinations should be carried out pre- and postoperatively to support the clinical findings. When available, additional imaging techniques such as digital radiology, fluoroscopy, scintigraphy, computed tomography and MRI may be indicated.

A basic set of dental extraction instruments includes:

1) molar spreaders or separators with the proper size blade and angle of handle to fit between the mesial and distal margins of the tooth to be removed
2) various molar extraction forceps to fit the crown of the tooth being removed
3) dental fulcrum
4) molar cutter sized to fit the tooth crown
5) set of dental chisels
6) set of dental elevators and curettes
7) general orthopedic instruments
8) material to pack or cover dental socket (iodoform gauze, acrylic, base plate wax or polyvinal siloxane impression material.)

Intraoral tooth extraction is best performed on the standing horse although general anesthesia may be necessary in a nervous or fractious animal. Sedative analgesics are administered, and the horse’s head is restrained in a steel frame, dental halter or head stand. Regional anesthesia is helpful in gaining patient cooperation. Pain management standards of care require regional or local infiltration anesthesia for extraction of permanent teeth. A full mouth speculum is needed to gain adequate access for working in the oral cavity. A headlight or fiberoptic light is essential for good visualization.

A tooth with a healthy crown is loosened by placing a spreader between the mesial and distal interdental spaces of the involved tooth. Special care must be taken when working on the 07 and 10 teeth to spread first on the side with the most support (between 07 and 08 or between 09 and 10) to avoid loosening 06 or 11. The spreader blades are carefully placed between the teeth at the gingival margin and the handles closed, bringing the blades partially together. Just enough force should be placed on the spreader to slightly move the tooth. The blades are held in this position
placing pressure on the periodontal ligaments, stretching them beyond the elastic limit over a 5 to 10 minute period. The spreader is removed and replaced on the opposite interdental space and the handles again closed, prying the teeth apart. This process is repeated until the spreader blades are easily closed both mesial and distal to the affected tooth. Teeth with split or damaged crowns may not be suitable for spreading and can be loosened with an equine dental osteotome and forceps. Next, the gingival mucosa is separated from the buccal and lingual edges of the tooth crown with a sharp dental elevator or osteotome. This will expose enough tooth surface area to allow forceps to be placed on the crown. It may be advantageous to remove a collar of alveolar plate on the buccal and/or lingual edge of the tooth crown to allow the forceps to be placed more securely. When using the dental forceps or elevator on the palatal side of the upper teeth, care should be taken not to damage the palatine artery.

The proper sized extraction forceps are placed on the tooth crown and secured with a length of rubber or elastic wrapped around the handles. Maximizing the purchase between the head of the forceps to the crown of the tooth is the most important aspect of instrument selection. Sagitally fractured cheek teeth may be able to have the food material flushed/removed to allow the fragments to come back together. This may allow for better placement/purchase of the extraction forceps on the clinical crown. The forceps are then rocked from side to side. The forceps handle should be moved over a very short range of motion to insure that the head of the forceps stay engaged on the tooth crown. This will help avoid abrading or breaking the tooth. Torsion is placed on the tooth until it is felt loosening in its socket. Undue haste or too great a force must be avoided. Care must also be taken to prevent crown damage from sudden movement of the horse’s head. Reapplication of the spreaders at this point can be helpful in loosening the tooth. When the tooth begins to loosen, a sucking sound can be heard, and frothing blood can be seen around the margins of the tooth. Progress can be checked by removing the forceps and palpating the crown to feel how loose the tooth has become. Keep in mind that the tooth is like a post in a hole. A great deal of movement must be placed on the portion of the post above ground to be reflected in a small amount of movement at the bottom of the post. In a young animal with the ratio of exposed crown to reserved crown and root favoring the latter, more movement of the exposed crown is needed to result in movement at the apex of the alveolus. Conversely, in an old horse with almost the entire crown exposed, even a slight movement in the crown would put great pressure on the roots. The tooth is locked in place because of the irregular shape of the reserve crown and roots mirroring the shape of the alveolus. The thin alveolar plate is relatively easy to deform into the spongy surrounding bone of a normal tooth. Diseased teeth may be surrounded by sclerotic bone making tooth loosening difficult. The combined process of disrupting the periodontal ligament and deforming the contour of the alveolus are essential to completely loosen the tooth.

Once the tooth is loose, the forceps should be repositioned to get a firm grip on the crown. A fulcrum or block is placed near the head of the forceps. Gradual, firm traction will readily bring the tooth from its socket. In the caudal recess of the oral cavity in a young horse with a long reserve crown, the tooth may require sectioning with a molar cutter to allow it to be delivered into the oral cavity. The tooth should be examined to make sure it has been removed in its entirety and no root fragments or slivers of crown have been left in the socket. The alveolus should be examined and any bone or tooth fragments removed. Operative radiographs will
confirm that the correct tooth has been removed and the alveolus is free of tooth and bone fragments.

Postoperatively lower cheek tooth sockets that are chronically infected from oral debris may need to be drained ventrally. This can be done with a ¼ inch Steinmann pin or ½ inch trephine hole made in the ventral lateral aspect of the mandible below the affected alveolus. To protect the open alveolus, place several 4 x 4 gauze sponges tied in the center to a length of ¼ inch umbilical tape. The tape ends are passed into the empty alveolus through the oral cavity and out the drainage hole. The gauze roll is wedged firmly into the space between the opposing teeth and secured in the socket with umbilical tape tied around another roll of gauze on the outside of the skin incision. The gauze should be changed every few days and the wound irrigated until the periphery of the dental socket is covered with healthy granulation tissue (five to ten days).

The alveolus should be protected for several weeks from oral contamination with a patch or plug of dental acrylic, dentalbase plate wax, polyvinyl siloxane or polymethylmethacrylate (PMMA). The entire plug should be about ¼ the length of the reserve crown of the removed tooth to allow room for the development of granulation tissue in the dental socket. The plug should extend only slightly above the top of the gingiva so that it is not involved in chewing. After the wax is in place, its surface is molded carefully with a finger to build a slight flange over the gingival line to seal the alveolus. This is different when using PVS, this rubbery material should be kept slightly below the gingiva to prevent it from prematurely coming out of the socket. Bone cement (PMMA) can be combined with radio-opaque contrast media or antibiotics if needed. If a hard setting material like PMMA or dental acrylic is used, the plug will need to be removed 6-8 weeks post extraction. This may require a four pronged extraction forceps.

The objective of exodontia should be to carefully plan and execute the extraction and protect the dental socket, thereby minimizing complications. Detailed descriptions for avoiding and managing surgical and post surgical complications can be found in the literature.5-9

References


Periodontal Disease Research and Treatment – UK Experiences

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Periodontal disease (periodontitis, paradontal disease, alveolar disease and alveolar periosteitis) describes inflammation of the supporting structures of the tooth, i.e. the gingiva, periodontal ligaments, cementum and alveolar bone. In addition to its obvious great importance in human dentistry, periodontal disease is also very important in dogs and cats, and also in farm animals including sheep and cattle. Coyler who worked on London draught and riding horses in the early 1900s described periodontal disease as a most significant equine dental disease (“the scourge of the horse”) and found a prevalence of 33% of this disease in an abattoir survey of 484 horses. However, examinations of photographs of Coyler’s equine skull specimens showed the periodontal disease to be secondary to interdental food impaction caused by other dental disorders such as diastemata and displaced cheek teeth (CT). Other early studies both in South Africa and the UK have also reported the presence of periodontal disease in horses.

Baker (1970) and Wafa (1988) found that 60% of horses over 15 and 20 years of age respectively, suffered from periodontal disease of their CT. However, this periodontal disease was usually secondary to other disorders such as displaced teeth or CT diastemata. Recent clinical studies on referred cases have also shown virtually all equine periodontal disease to be associated with abnormalities of the interdental (interproximal) spaces, such as CT diastemata.

Figure 1. Normal interdental area of mandibular cheek teeth – showing tight apposition of the adjacent cheek teeth without any space for food trapping. Note the pale-coloured normal gingival, tightly attached to the peripheral cementum.
with minimal evidence of periodontal disease associated with normally apposed teeth such as illustrated in Figure 1. Periodontal disease in donkeys is also significantly associated with diastemata, overgrown teeth, displaced teeth and increasing age. Both Baker and Wafa also recognised a mild transient periodontitis associated with dental eruption, in 40-50% of immature skulls. Little pathological research has been performed on equine periodontal disease until recently and it is likely that the constantly remodeling periodontal tissues because of their hypsodont teeth makes them differ from those in brachydont species – see papers by C. Staszyk in these proceedings.

Periodontal disease in brachydont teeth is initiated by the adherence of organic dental plaque and bacteria to teeth. Later, the plaque often becomes calcified to form dental calculus that consists of 70-90% minerals. All teeth including equine teeth have a covering of organic matter (mainly mucopolysaccharides and glycoproteins of salivary origin and attached oral bacteria) (Fig. 2). If this is a thin layer, it can be described as a normal organic pellicle. If it becomes thicker it can then be classified as dental plaque. A thick layer of dental plaque can be present in the interdental spaces even in apparently normal horses (Fig. 3). Unlike in brachydont species, equine dental plaque generally does not become calcified, an exception being the plaque around the lower canine teeth, and less commonly on the buccal aspects of the rostral maxillary CT and incisors of horses with intercurrent dental problems. The main component of equine dental calculus is calcite that has a chalky appearance. The associated, usually low-grade periodontal disease adjacent to the calculus around canine teeth usually resolves following its removal. In general dental calculus is not a significant problem in horses that do not have intercurrent dental disorders and this low prevalence may be due to the prolonged time horses spend masticating fibrous food that prevents a buildup of excessive plaque that could later calcify.

Figure 2. Equine cheek teeth stained to show a thick layer of uncalcified dental plaque (red colour). Image courtesy of A. Cox and S. Smith.
In brachydont teeth, periodontal disease starts as gingivitis, with loss of the normal tight gingival attachment to the adjacent teeth. This gingiva then becomes inflamed due to mechanical irritation, e.g. to impacted food particles and from chemical irritation from bacteria, food and plaque, and later even due to the body’s own immune reaction, e.g. inflammation caused by neutrophil breakdown products. As the gingival destruction continues, the progressively larger gingival and later periodontal defect becomes further impacted with food and the process perpetuates itself, with the periodontitis extending deeper into the periodontal ligament and later also spreading along the buccal and lingual/palatal margins of teeth, forming large periodontal food pockets \(^{11,12}\) (Figs. 4 & 5).
Figure 5. The diastema between these two cheek teeth in an old horse has caused severe periodontal disease, including destruction of the periodontal ligaments and deep erosion of the peripheral cementum (black and pitted).

This inflammation and concurrent bacterial infection may even extend to involve the alveolar and supporting bones, causing bone remodeling, or even bone necrosis and infection. Eventually so much periodontal ligaments are lost that the tooth becomes loose and may even be spontaneously lost. More localised extension of the periodontal disease in an apical direction can lead to infection of the periodontal ligaments at the apex, ischaemia or infection of the pulp and death of the tooth. Wide and “open” diastemata are less likely to trap food and cause periodontal disease (Fig. 6). A periodontal disease grading system (0-4) used in small animals that is based on the percentage of dental attachment loss could be used in equids (Table 1).

Figure 6. This specimen has wide and open (same width at its occlusal and gingival aspect) diastema that does not tightly trap food and consequently it has normal epithelium deep in its base. This latter finding in this size and shape of diastema is the rationale behind diastema widening treatment.
Table 1. Equine Periodontal Disease Grading System

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 0</td>
<td>normal</td>
</tr>
<tr>
<td>Stage 1</td>
<td>gingivitis</td>
</tr>
<tr>
<td>Stage 2</td>
<td>early periodontal disease (up to 25% attachment loss)</td>
</tr>
<tr>
<td>Stage 3</td>
<td>moderate (25-50% attachment loss)</td>
</tr>
<tr>
<td>Stage 4</td>
<td>severe (greater than 50% attachment loss)</td>
</tr>
</tbody>
</table>

In the author’s experience, almost all equine periodontal disease is associated with abnormal spacing between teeth (Figs. 4 & 5) including due to primary diastemata, displaced or supernumerary teeth as discussed in other proceedings of this Focus meeting. Additionally, with generalized, severe dental disease such as wavemouth and shearmouth, especially in geriatric horses, restricted masticatory action can lead to generalized peripheral caries and associated periodontal disease. Periodontal disease also occurs adjacent to incisors or canine teeth affected with the EOTRH syndrome as discussed elsewhere in this proceedings. Some clinicians claim that CT overgrowths that have caused “shifting” of teeth to be the main cause of diastema in their patients. Such occlusal overgrowths are rare in the diastemata cases examined at our clinic. Additionally, a recent histological study of equine periodontal disease found periodontal disease to be associated with physical abnormalities of the interdental spaces.11

Treatment

Cases with periodontal disease should be examined for predisposing factors and these factors should be addressed whenever possible. Overgrowths that may have caused dental drift should be reduced in stages – in order to prevent pulpar exposure or thermal damage. Food should be removed from diastemata and periodontal pockets. Some clinicians claim that the removal of impacted food alone is curative – but if so – why did food become impacted at these sites in the first place? The author widens all valve-like diastemata (Figs. 7 & 8) that are causing food impaction and has reported a good success in most, even longstanding cases13 and the techniques have been well described.14 There is a significant risk of damaging the adjacent pulps – that are closest to the distal aspect of the rostral tooth15 and therefore as much tooth as possible should be removed from the mesial aspect of the caudal tooth. The widening should not be performed for more than 5 seconds at a time – constantly cooling the teeth and assessing the site with a dental mirror or oral endoscope.
References


Surgical Extraction of Canine Teeth

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Introduction

The main function of equine canine teeth is defense and offense. Though evolution has significantly reduced the size of these teeth through the millennia and in females mostly eliminated them, canine teeth still represent a part of the dentition worthy of clinical and radiographic examination. The maxillary canine teeth are located in the middle of the interdental space in the rostral aspect of the maxillary bone, and the mandibular canine teeth are located in the interdental space of the mandible just caudal to the third incisors. Canines erupt between 4 to 6 years of age. The structure of the equine canine tooth is less complex than the incisors and cheek teeth, and in outward appearance may seem to be more brachydont in nature. When looked at more closely though the crown is superficially covered with peripheral cementum and coronal enamel extends deep into the alveolus suggesting a tooth more hypsodont in nature. The average length of a canine tooth from crown tip to apex is 5-7 cm, and only a 1/4 to 1/3 of this is clinical crown. Canine teeth do not continually erupt like the incisors and cheek teeth, so the length of the tooth within the alveolus changes minimally. Therefore, extraction of the equine canine tooth can be a significant undertaking requiring a surgical approach.

Male horses usually possess all four canine teeth, while in females their presence is variable. Roughly 7-30% of female horses have canine teeth depending on the reference. In males and females, it is possible to find deciduous vestiges (spicule-like structures 0.5-1 cm long), unerupted teeth, or partially formed teeth located under the alveolar mucosa in the region of the interdental space. If present, a bulge or irregularity of the bone and/or mucosa may be palpated suggesting the need for radiographic examination. Some unerupted or impacted canine teeth in horses can be quite sensitive leading to bit discomfort. Depending on the nature of the problem, treatment can range from an operculectomy (surgical excision of mucosa over an unerupted tooth) to extraction. In the author’s opinion, if unerupted canine teeth do not appear to be causing the horse any discomfort, no treatment is necessary at that time. The owner is informed of the condition and asked to monitor for signs of sensitivity and swelling in the future.

Pathology associated with canine teeth has probably been studied the least of all tooth types within the equine oral cavity, but significant and painful pathology can be found associated with this tooth. Trauma leading to tooth fracture and avulsion are not uncommon. Mandibular fractures spanning the interdental space can involve the canine necessitating extraction or root canal therapy. Pulp exposure from past over-reduction or abrasion has been reported. It is important to note that especially in young teeth a wide pulp chamber may extend to within 5 mm of the occlusal surface. Therefore, prophylactic reduction of canine teeth risks pulp exposure and is discouraged.
Tooth resorption associated with equine odontoclastic tooth resorption and hypercementosis (EOTRH) is well documented to be associated with the canine and incisor teeth. Therefore, in cases of EOTRH radiographs of both the incisors and canines should be taken. Resorptive lesions in older horses can be found under excessive tartar deposition on the mandibular (more common) and maxillary teeth. Exposing these lesions after removal of tartar will cause discomfort for the horse and the practitioner should be prepared to address the problem.

Due to the length of the reserve crown and root situated within a curved alveolus, basic principles of surgical dental extraction will need to be utilized for removal. In general, a mucogingival flap will need to be raised to expose the underlying labial bone. Depending on the tooth and the pathology affecting the tooth, 60-80% of the labial bone plate will need to be removed with a high-speed dental drill to allow for elevation. Once the embedded tooth is uncovered, a dental elevator is used to fatigue the periodontal ligament and the tooth is removed with extraction forceps. All bone margins should be smoothed, and the site should be debrided and flushed clean. The flap will need to be closed in a tension free manner; therefore, the periosteum underlying the mucosa will need to be cut to allow for free movement of the flap. The flap is sutured closed in a simple interrupted pattern. Endodontic therapy can sometimes be used to salvage some apically infected canine teeth to avoid the trauma of oral surgery.

**Materials and Methods**

**Equipment list:**

- Basic surgery tray (scalpel, forceps, metzenbaum and mayo scissors, needle driver, etc)
- Dental elevators (winged elevator sizes 5mm or 6mm – Miltex)
- Extraction forceps
- Periosteal elevator (Molt, Freer, or Selden)
- High-speed dental unit or pneumatic high-speed surgical drill with assistant irrigation
- Round carbide bur (dental – size 8; surgical – 4mm or 6mm)
- Round diamond bur (dental – 023; surgical – 4mm or 6mm) – OPTIONAL
- Bone curette
- Antimicrobial flush (0.12% chlorhexidine solution)
- Monocryl 2-0 on cutting needle

**Procedure:**

1. Properly restrain and sedate the patient and place regional analgesia.
2. Take preoperative radiograph to determine the condition of reserve crown, root, and periodontal ligament. KNOW YOUR ENEMY!
3. Flush site with antimicrobial rinse and remove major debris from tooth and surrounding tissue.
4. Create mucogingival flap with two releasing incisions
   a. Mesial incision: start cutting on mesiolabial aspect of tooth and extend the incision apically through gingiva, mucogingival junction, and roughly 20-30 mm of alveolar mucosa along the line angle of the tooth– press firmly to cut through the periosteum.
b. Distal incision: start cutting on distal aspect of tooth and extend the incision distally through gingiva, mucogingival junction, and roughly 15-20 mm of mucosa – press firmly.
c. Labial incision: lightly run the tip of scalpel blade into gingival sulcus – the blade is parallel to tooth moving in rostrocaudal direction to cut through gingival attachment.

5. Elevate flap with periosteal elevator. It is very important to maintain the dissection plane DEEP to the periosteum with the instrument engaged on bone.
   a. Remove all remaining soft tissue from the bone.
   b. Releasing incisions can be slightly extended if more bone visualization is necessary.

6. Using high-speed drill with irrigation remove 60-80% (exact amount depends on pathology and condition of periodontal ligament) of the labial alveolar bone plate.
   a. Start at the clinical crown and work apically letting the crown guide continued bone removal.
   b. Cleanly expose the periodontal ligament on mesial and distal aspect of tooth.

7. Elevate the tooth with appropriately sized winged elevator. The curvature of the working end should match the diameter on the root.
   a. SLOW AND STEADY PRESSURE…..twist and hold 5-10 seconds. Wriggling will get you nowhere fast and frustrated.
   b. If elevating for over 5 minutes without any mobility, drill away a little more alveolar bone and make sure the mesial and distal edges are free of overlapping bone.

8. Once the tooth becomes mobile, grasp it with extraction forceps and pull the tooth out of alveolus. Do not lever the tooth side to side since this will lead to root fracture.

9. Using a bone curette, completely debride the alveolar socket and, as necessary, the surrounding bone.

10. Take a radiograph to ensure the entire tooth has been extracted. This is very important in resorption cases to ensure tooth completely removed.

11. Perform alveoloplasty. Smooth the rough labial and crestal bone edges either with round diamond (preferred) or carbide bur.

12. Flush the site completely to remove all diseased tissue and surgical debris.

13. Release the mucogingival flap and freshen the soft tissue edges.
   a. Completely transect the periosteum in rostrocaudal direction at base of mucogingival flap. This incision should only be 1-2 mm deep.
   b. If some restriction still remains, metzenbaum scissors can be used to gently undermine the flap further in rostrocaudal direction.
   c. The flap should completely cover extraction site and sit in place pre-closure WITHOUT tension.

14. Suture the extraction site.
   a. Monocryl 2-0 on a cutting needle is used for closure.
   b. Simple interrupted sutures are spaced every 5 mm.
   c. The occlusal line is closed first followed by releasing incisions.
   d. Use full thickness, wide (5-7 mm) bites to anchor knots.
   e. Surgeon’s throw first followed by a minimum of five additional throws.
   f. Cut suture end to roughly 3-4 mm in length.
15. Take postoperative radiograph to document final outcome of procedure.  
16. Provide adequate postoperative pain management and antibiotics if indicated.

Discussion

Surgical extraction of teeth may sound simple, but experience demonstrates how challenging this procedure can be especially when first learning all the steps involved. Canine tooth extraction can be complicated and frustrating for experienced dental surgeons, and a practitioner should evaluate his ability to perform this procedure (training, experience, instrumentation, etc.) before attempting it. Case referral may be in the best interest of the patient and all parties involved. In the past, canine teeth have been extracted by surgical and nonsurgical procedures with various outcomes. The point of the procedure outlined above is to maximize success while minimizing uncontrolled collateral damage, frustration, and time. The author does not recommend extraction of a canine tooth in a nonsurgical manner unless the tooth already displays significant mobility and the reserve crown and root are intact. The high-speed drill dramatically increases the practitioner’s ability to precisely remove bone and deal with more complicated extractions (fractured reserve crown/root, resorbed teeth, and ankylosic periodontal ligament) in an exacting manner.

A few points should be remembered. The mouth is slippery and the horse moves. Always hold instruments in a manner that will reduce trauma upon slippage or movement. Keep anatomy in mind when drilling, debriding, and elevating. The mental foramen is located just caudal to the apex of the mandibular canine tooth. Ankylosis of the periodontal ligament is not uncommon and makes extraction very challenging. If the standard approach is not progressing, the author will transect the tooth at the level of the middle of the reserve crown. The coronal portion of the tooth is extracted and the apical portion is drilled in a circumferential manner creating a “moat” around the remaining tooth fragment. At this point, the apical portion of the tooth can usually be extracted. Finally, if you are going to create a flap to remove a tooth, remove the ENTIRE tooth to prevent future infection and complication.

It should be noted that mucogingival flaps in horses are notorious for dehiscence especially on the mandible. The reason behind this is not exactly known, but time devoted to mastication, labial and frenulum attachments, gravity and tongue action have all been thought to attribute to this complication. In the author’s experience, dehiscence if present usually occurs between days 5 – 10, when granulation tissue, partial primary closure, and wound contraction have already started to occur at the surgical margin, and the dehiscence rarely results in full exposure of the surgical site. Sutures involved with the dehiscence are removed, and the owner is instructed to flush the wound twice daily until complete healing has occurred by second intention (usually 1-2 weeks).

Sometimes severely resorbed teeth make complete extraction nearly impossible, and there has been discussion within the dental community as to whether clinical crown amputation is acceptable for these teeth. Clinical crown amputation involves elevation of the gingiva and 2-3 mm of surrounding mucosa without releasing incisions to remove the clinical crown via burring down to the level of the alveolar ridge. The gingiva and mucosa are closed with a few sutures. There is no study documenting the long-term success of this procedure in horses; however, in
cats with severe tooth resorption, crown amputation is acceptable and successful if no periodontal ligament or regional pathology is visible on radiographs. Whether horses are similar to cats in this manner is unknown. The author suspects that the degree of regional/dental necrosis, bulbous hypercementosis, and inflammatory tissue reported by Staszyk⁴ would lead to postoperative regional inflammation and infection if portions of an incompletely resorbed tooth were purposefully left in the alveolus. The practitioner and the owner should carefully weigh the pros and cons of this approach if resorption is severe enough for this procedure to be considered.

In conclusion, extraction of equine canine teeth can be rewarding for both the patient and practitioner when performed in a well thought-out surgical manner.

References

Review of Anatomy and Surgery of the Paranasal Sinuses of Horses

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Take Home Message

The complexity and vascularity of the sinuses makes surgical treatment of horses affected by disease of paranasal sinuses difficult. Performing surgery of the paranasal sinuses with the horse sedated and standing, rather than anesthetized and recumbent, eliminates the risks of general anesthesia, decreases expense, and simplifies the surgery by reducing hemorrhage.

Introduction

The clinician should have good knowledge of the anatomy of the equine paranasal sinuses to diagnose and treat horses for disease of the paranasal sinuses. The clinician must be able to create a frontonasal or maxillary osteoplastic flap to treat many horses for disease of the sinuses because many diseases of the sinuses can be resolved only by surgery.

Anatomy of the Paranasal Sinuses

The paired paranasal sinuses of the horse include the frontal, conchal (dorsal, middle, and ventral), rostral and caudal maxillary, and sphenopalatine sinuses. All of the sinuses of one side of the head communicate directly or indirectly with the middle nasal meatus through the nasomaxillary aperture. The rostromedial aspect of the frontal sinus communicates so freely with the dorsal conchal sinus that the two are referred to together as the conchofrontal sinus. The conchofrontal sinus joins the caudal maxillary sinus through the frontomaxillary aperture. The caudal limit of the conchofrontal sinuses is at the level of an imaginary line through the supraorbital foramen, and the rostral limit is at the level of an imaginary line perpendicular to the facial crest, halfway between the infraorbital foramen and the medial canthus of the eye. The rostral limits can also be found by passing the thumb and index finger caudally along the nasal bones until the digits begin to diverge from each other.

In addition to the dorsal conchal sinus, the horse also has middle and ventral conchal sinuses. The small, middle conchal sinus is located medial to the caudodorsal part of the caudal maxillary sinus with which it communicates. The more rostrally located ventral conchal sinus is continuous dorsally with the rostral maxillary sinus medial to the infraorbital canal.

The rostral and caudal maxillary sinuses are separated by a bony septum, the maxillary septum, which is usually located at the level of the 2nd maxillary molar. The rostral and caudal maxillary sinuses communicate with the middle nasal meatus through the shared, slit-like nasomaxillary aperture. The rostral maxillary sinus invaginates the maxilla, and the larger, caudal maxillary sinus invaginates the maxilla, lacrimal, zygomatic, and ethmoid bones. The
The rostral limit of the maxillary sinuses is a line drawn from the rostral extremity of the facial crest to the infraorbital foramen, and the dorsal limit is a line drawn from the medial canthus of the eye to the infraorbital foramen. The ventral limit is the facial crest, and the caudal limit is the floor of the orbit. The caudal maxillary sinus communicates dorsally with the conchofrontal sinus through the large frontomaxillary aperture, and caudally with sphenopalatine sinus.

The maxillary sinuses are invaginated by the alveolar bone surrounding the roots of the last four cheek teeth. The mesial portion of the apex of the 4th maxillary premolar usually lies rostral to the rostral maxillary sinus, and the distal portion of the apex usually lies within the rostral maxillary sinus. The apex of the 1st maxillary molar lies entirely within the rostral maxillary sinus, and the apex of the 2nd maxillary molar lies directly beneath the maxillary septum, which separates the rostral and caudal maxillary sinuses. The apex of the 3rd maxillary molar lies entirely within the caudal maxillary sinus. The maxillary sinuses expand ventrally as the teeth continuously erupt.

The sphenopalatine sinus extends caudally from the caudal maxillary sinus and borders on parts of the palatine, sphenoid, ethmoid, and vomer bones. The sphenoid parts may be absent. The opening of the sphenopalatine sinus is located medially to the infraorbital canal.

**Surgery of the Paranasal Sinuses**

The paranasal sinuses can be exposed through a frontonasal osteoplastic flap or a maxillary osteoplastic flap. The frontonasal flap is the most versatile because it is easier to create and provides direct or indirect access to all compartments of the ipsilateral paranasal sinuses. The maxillary flap is more difficult to create than is the frontonasal flap, and it provides poor access to the ventral conchal sinus of horses less than 6 years old, but it provides good access to the rostral and caudal maxillary sinuses. The maxillary flap is most commonly used to expose the apex of the first or second maxillary molar. The apex of the third maxillary molar is often best exposed through a frontonasal flap.

**Frontonasal Osteoplastic Flap**

To create a frontonasal flap, a three-sided, rectangular, cutaneous incision, with slightly rounded corners, is created over the conchofrontal sinus and extended through the periosteum. The caudal portion of the incision is created perpendicular to the dorsal midline, midway between the supraorbital foramen and the medial canthus of the eye. This incision extends laterally from the dorsal midline to a point about 1.5 to 2 cm medial to the medial aspect of the rim of the orbit. The rostral portion of the incision begins on the dorsal midline, 1 to 2 cm caudal to where the nasal bones begin to diverge, and extends laterally, perpendicular to the long axis of the head and parallel to the caudal portion of the incision to an imaginary line extending from the medial canthus of the eye to the nasoincisive incisure. The lateral portion of the incision connects the most lateral extent of the caudal and rostral portions of the incision. The incision should not cross the nasolacrimal duct, which courses between the medial canthus of the eye and the nasoincisive incisure. A portion of the lateral segment of the incision can be angled rostromedially, if necessary, to avoid the course of the duct. The periosteum is reflected for a few millimeters on each side of the periosteal incision using a periosteal elevator.
Bone exposed by the incision is cut with an oscillating bone saw or a motorized cast cutter with a sharp blade or with a mallet and osteotome. To avoid overheating bone, the blade of the saw should be cooled with sterile, normal saline solution. The bone is cut at a 45-degree angle so that the flap’s external lamina is slightly larger than its internal lamina.

The flap is partially elevated using a chisel or periosteal elevator so that the surgeon’s fingers can be introduced beneath the flap. The flap is fractured at its base, close to the dorsal midline. The flap remains hinged at its base by skin, subcutaneous tissue and periosteum. Elevating the flap exposes the conchofrontal sinus, which communicates with the caudal maxillary sinus through the large frontomaxillary aperture. When the architecture of the sinuses has not been distorted by disease, the maxillary septum can be seen beneath the rostral edge of the frontomaxillary aperture. To expose the rostral maxillary and ventral conchal sinuses, the maxillary septum is removed with a scissors. The ventral conchal sinus is located medial to the infraorbital canal, and the rostral maxillary sinus is located lateral to the canal. The infraorbital canal is supported by a thin plate of bone that separates these two compartments. All or a portion of the reserve crowns of the 4th premolar and 1st and 2nd molars of horses less than 4 years old completely fill the rostral maxillary sinus.

The medial wall of the dorsal or ventral conchal sinus is often perforated to establish drainage of the sinuses into the ipsilateral nasal cavity. A portal for drainage need not be established if the nasomaxillary aperture is patent, and rarely is the nasomaxillary aperture obstructed. Blood or lavage fluid seen exiting the nasal cavity can be used as evidence that the nasomaxillary aperture is patent. A portal to remove gauze packing or to allow lavage of the sinuses can be created into the frontal sinus, caudal to the caudal border of the flap, or into the caudal maxillary sinus about 2 cm ventral and 2 cm rostral to the medial canthus of the eye, through a 2- to 3-cm, longitudinal, skin and periosteal incision, using a 3/8-inch Galt trephine.

Maxillary Osteoplastic Flap

The most common indication for creating a maxillary osteoplastic flap is repulsion of a maxillary molar, which is best performed with the horse anesthetized. Exposing the apex of a maxillary molar through an osteoplastic maxillary flap, rather than through a trephine hole, permits visual examination of a large portion of the sinuses and permits manipulation of dental instruments.

To create a dorsally hinged, osteoplastic maxillary flap, a three-sided incision through the skin, subcutis, and periosteum, with rounded corners, is created within the confines of the boundaries of the rostral and caudal maxillary sinuses. The cutaneous incision begins at a point about 1 cm rostral to the orbit, slightly below the medial canthus, and extends ventrally, perpendicular to the facial crest to a point about 1 cm dorsal to the facial crest. The incision is extended rostrally, parallel to the facial crest to a point about 1 cm caudal to the rostral end of the facial crest, and turned dorsally and extended to a point about 1 cm caudal to the infraorbital foramen. The rostral portion of the incision extends into the nasolabialis and levator labii superioris muscles and may transect the angularis oculi artery and vein.

Periosteum is reflected slightly, and the maxillary bone is cut along the incision, at a 45-degree angle, using an oscillating saw or a mallet and an osteotome. The flap is pried upward until it
fractures dorsally to expose the interior of the rostral and caudal maxillary sinuses. Septal attachments to the bone must sometimes be severed with an osteotome before the flap can be prided dorsally. If at the conclusion of surgery, the need for lavage of the sinuses is anticipated, a portal for lavage can be created over the frontal bone into the conchofrontal sinus or through the maxillarary bone, caudal to the flap, into the caudal maxillary sinus.

After returning the frontonasal or maxillary flap to its normal position at the end of surgery, the subcutaneous tissue is apposed with absorbable sutures, and the margins of the skin incision are apposed with skin staples. Because the bone is bevelled, it need not be attached to surrounding bone, and apposing the margins of the inelastic periosteum is difficult to impossible. The flap is compressed with a bolus bandage or with gauze swabs anchored by elastic, adhesive tape placed in a figure-of-eight fashion around the head. Gauze packed into the sinuses can be removed through the trephine hole, usually the next day, and the stent or elastic bandage is removed at 4 to 7 days. The portal created for removing gauze packing or for lavage of the sinuses can be closed with staples or sutures after the portal is no longer required.

Creating an Osteoplastic Flap with the Horse Standing

Surgery of the paranasal sinuses is usually performed with the horse anesthetized and recumbent, but most surgeries of the paranasal sinuses that can be performed through a frontonasal flap can also be performed with the horse standing, thereby eliminating the risks and expense of general anesthesia. Surgery of the paranasal sinuses performed with the horse standing results in less hemorrhage than surgery performed with the horse anesthetized and recumbent. When surgery of the sinuses is performed with the horse standing, the structures within the sinuses are oriented in a normal position.

A horse selected to receive surgery of the sinuses while standing should be compliant and should not resent movement of hands and instruments about its head. Surgery of the paranasal sinuses performed with the horse standing is most safely performed with the horse restrained in stocks. The horse is sedated with detomidine HCl (0.01 – 0.02 mg/kg IV or 0.03-0.04 mg/kg intramuscularly) and butorphanol tartrate (0.02 – 0.05 mg/kg, IV) or morphine (0.15 mg/kg, IV). The horse can be re-sedated with xylazine (0.5mg/kg, IV) or detomidine (0.01mg/kg, IV), when needed. The horse’s head should be supported on a stand.

The proposed site of incision is infused subcutaneously with local anesthetic solution, and the paranasal sinuses are desensitized by anesthetizing the ipsilateral maxillary nerve or by infusing 30 to 40 mL of local anesthetic solution into the sinuses through a small hole created several centimeters medial to the medial canthus of the eye with a Steinmann pin. To anesthetize the maxillary nerve, a 20-gauge, 3.5-inch, spinal needle is inserted ventral to the zygomatic process of the malar bone and dorsal to the transverse facial vessels on an imaginary line drawn perpendicular to the long axis of the head through the lateral canthus of the eye, until the needle strikes bone, usually at a depth of about 5.0 to 6.5 cm (2 to 2.5 inches). The horse may jerk its head if the needle contacts the nerve. Ten to 15 mL of local anesthetic solution is deposited at this site. The ipsilateral paranasal sinuses are usually desensitized within 15 minutes. Another technique of anesthetizing the maxillary nerve at the pterygopalatine fossa is to insert the point of a 20- to 22-gauge, 8.9-cm (3.5-inch) spinal needle just ventral to the ventral border of the
zygomatic process of the temporal bone at the narrowest point of the zygomatic arch and direct the needle rostromedially and ventrally in the direction of the third molar of the contralateral maxillary dental arcade.6

The surgical site is prepared for surgery after the sinuses and skin at the proposed site of incision are desensitized. The surgical site should not be draped, so that the horse’s reactions to sinusotomy can be monitored. A lip twitch should be applied to the horse when the bone is cut to prevent the horse from moving. The paranasal sinuses are inspected, and the horse is treated for disease encountered. The flap is replaced and sutured as described above.

References

Minimally Invasive Transbuccal Surgery and Screw Extraction

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Take Home Message

An oral extraction of cheek teeth has its limits if the clinical crown of a tooth is broken. Minimally invasive transbuccal surgery is a useful approach to continue oral extraction and allows the screw extraction (acc. to Stoll)\textsuperscript{10} in these difficult cases.

Introduction

Minimally invasive transbuccal surgery was developed to provide a direct approach to difficult accessible areas in the mouth, for example alveoli with a fractured crown or retained roots. The transbuccal approach allows the use of instruments and endoscopes through a hole in the cheek. The use of straight instruments allows for better movement of instruments and application of increased force on the tips of the instruments. The transbuccal approach may be used in the standing horse and in lateral recumbency as well. Screw extraction (acc. to Stoll) was developed to extract teeth which are not extractable with forceps in oral extraction procedure. Drilling via transbuccal approach into the reserve crowns of fractured teeth gives the chance to extract these teeth with a screw. Thus, minimally invasive transbuccal surgery is an alternative to trephination and repulsion in cases of fractured crowns and other cases of impossible oral extractions.

Materials and Methods

Minimally invasive transbuccal surgery and screw extraction is recommended for certain teeth, i.e. fractured crowns, absent crowns, malformed and dislocated teeth not allowing the for the use of spreaders and forceps (Fig. 1).

Standing Sedation

Transbuccal surgery can be performed routinely in horses with a combination of sedation and local anaesthesia. An IV catheter is placed and detomidine\textsuperscript{a} (0.01 – 0.02 mg/kg BW) is used for sedation. After this initial dose, the horse can be connected to a detomidine drip (60 mg detomidine + 1000 ml saline) at 1 drop per second depending on effect. To increase the analgesic effect of the sedation and possibly slow tongue movement, butorphanol\textsuperscript{b} (1mg/100 kg BW) can be added. If there is still too much tongue movement, diazepam (0,5-1 mg/100 kg BW) can be given as well. Beside the relaxation of the tongue the whole horse becomes more relaxed and ataxic. So this drug combination should be used carefully or preferably in stocks. The duration of the effect of diazepam is short, lasting about 10 to 15 minutes. To desensitize the mucous membranes of the mouth, one can spray lidocaine into the oral cavity. This procedure often makes the horse more tolerant to oral manipulation. Subgingival infiltration of 2 ml 2%
mepivicaine buccal and palatal or lingual of the affected tooth desensitizes the gingiva very effectively. In cases vital pulp is expected the apical nerve supply can be anesthetized by nerve blocks. For extractions of maxillary cheek teeth the maxillary foramen block is used (Extraperiorbital fat body injection, EFBI Staszyk et al 2008). 10-15 ml 2% mepivicaine are injected into the extraperiorbital fat body. Mandibular cheek teeth become anesthetized with the mandibular foramen block. 20 ml 2% mepivicaine are injected close to the mandibular foramen.

Minimally Invasive Transbuccal Approach

On the side where the transbuccal approach will be performed, the skin of the cheek is clipped, shaved and aseptically prepared. After shaving, it is very important to identify the branches of the facial nerve and the facial artery and vein. In horses with thin skin these structures are easy to find. If the nerves and vessels are not visible, one must try to palpate them. It is also important to avoid damaging the parotid duct. The easiest way to identify the parotid duct under the skin is to put a catheter (diameter 2 mm, length 50 cm) into the duct through the oral papilla (Fig. 2). To prevent damaging these sensitive structures it is helpful to mark their position with a pen (Fig. 3). In most cases the transbuccal approach is made between the dorsal and the ventral buccal branches of the facial nerve. Depending on the affected tooth the approach can be made either rostral or caudal to the facial artery. To desensitize the skin and the muscles of the cheek, 2 ml 2% lidocaine are injected subcutaneously and 3 ml are infiltrated into the deeper tissue of the incision area.

After 5 minutes a 4 mm superficial incision will be made only through the skin with a scalpel. The transbuccal approach is made by penetration of the cheek with an 8 mm trocar system® (Fig. 4). The trocar stays in place during the complete transbuccal surgery (Fig. 5). All instruments are used through the trocar to keep the tissue of the cheek protected and clean. To target the spot for the approach, a mouth speculum is used and the spot is marked from the oral cavity through the cheek with a fingertip. After the dental procedure is finished, the skin is closed by 1-3 simple interrupted sutures or staples. In cases in which the approach goes through the masseter muscle, additional closure of the oral mucous membrane is recommended. To prevent wound infection,
the horses are kept on antibiotics for 6 days. After 10 to 14 days the sutures or staples can be removed.

Figure 2. Catheter is placed in the parotid duct for better palpation.

Figure 3. (a) Dorsal and (b) ventral buccal branches of the facial nerve, (c) parotid duct, (d) facial artery and vein.

Figure 4. Trocar in pushed through the cheek.

Figure 5. Trocar stays in place during complete transbuccal surgery and screw extraction.

Transbuccal Extraction, Screw Extraction

Loosening

Similar to oral extractions, the procedure begins with interdental spreading. Dental elevators through the transbuccal trocar are inserted alternately into the mesial and distal interproximal spaces until loosening is achieved (Fig. 6).

Drilling

To mark the position of the affected tooth, radiographs are taken with skin staples placed near the transbuccal approach and in the area the roots are expected.
It is recommended to start drilling with a 3 mm drill before using the 5 mm drill. The 3 mm hole can be made with a 90° oral drilling unit or with a long drill through the transbuccal approach. A 5 mm hole is drilled through a drill sleeve to protect the trocar (Fig. 7). In small teeth the complete length of the reserve crown is used, in long teeth the hole is drilled about 40 mm deep. Because of the inclined approach through the cheek the drill is usually directed palatal. Therefore drilling through the transbuccal approach should start at the buccal aspect of the tooth. The drilling hole is flushed to remove tooth chips. A 6 mm tap is inserted through the trochar and screwed into the hole to create an accurate thread for the extraction screw (Fig. 8).

Screw Extraction

In the direction as the tap a 6 mm pin with a thread on one side and a stopper on the other side is screwed into the tooth (Fig. 9). A slotted hammer is slipped along the pin and pushed to the stopper many times to extract the tooth or a retained part of a tooth (Figs. 10 & 11).
Figure 9. Extraction screw (6 mm) in place.

Figure 10. Slotted hammer pulls the tooth by many strokes to the stopper at the extraction screw.

Figure 11. Extracted tooth.

If the tooth is moldered it can happen that the thread is not strong enough to pull the tooth out of the alveolus. The screw can pull out of the thread. In these cases a new hole can be drilled beside the first one to start screw extraction again. If the tooth is too weak for screw extraction, more holes can be drilled into the tooth in order to fracture the tooth into small pieces. Subsequently, these pieces can be easily extracted with a dental elevator through the transbuccal trochar (Fig.
After water flush and endoscopic check, the alveolus is half filled by crystallised honey and covered by iodoform gaze.

Figure 12. Extracted fragments.  
Buccotomy trocar system.

Results

From 100 horses presented for oral extraction 22 horses needed transbuccal surgery. Twenty-six teeth or fragments from teeth were extracted with transbuccal surgery. 1 horse had transbuccal surgery on both sides and 3 horses had 2 extractions at one side.

The disposition of teeth was: Maxillary 09th 14 cases (53,84%), upper 10th 5 cases (19,23%), mandibular 08th 3 cases (11,54%), lower 09th 2 cases (7,69%), upper 07th 1 case (3,85%), upper 08th 1 case (3,85%). Eight teeth/fragments were extracted by transbuccal surgery with dental picks without screw extraction.

18 teeth were extracted by transbuccal surgery and screw extraction.
10 teeth were extracted with drilling 1 hole.
4 teeth needed a second hole.
4 teeth with successful screw extraction had at least one root fragment that had to be extracted by dental picks through the transbuccal trocar.
4 teeth were broken in parts or had to be dissected in parts for extraction.
In 4 cases a dental pick or a drill penetrated the maxillary sinus.
All 26 teeth were completely extracted after transbuccal surgery.

Complications

In 7 cases, facial nerve paralysis persisted for several hours after local infiltration of lidocaine into the cheek.

Mild wound edema occurred in 18 cases for several days. One horse had swelling and purulent wound discharge for 1 week at the transbuccal incision. One horse where the drill penetrated the maxillary sinus had mild mucous nasal discharge for 7 days after surgery. No further treatment was required.
Discussion

Cheek teeth with a fractured or missing crown are a challenge for oral extraction.\textsuperscript{2-6} If a crown is fractured to the gingival level it is impossible to use a molar separator to loosen the tooth.\textsuperscript{8,9} The alternative use of 90 degree dental picks for extraction procedures is limited due to the restricted range of the mouth.

The described transbuccal surgery facilitates different dental procedures by allowing the use of straight instruments through the cheek. One of the most common situations in which transbuccal surgery is used is a retained root fragment or a retained piece of the reserve crown. Access to the tooth is very direct and creates a lot of extra work space beside the intraoral cavity. It becomes easier to extract fractured cheek teeth and root fragments because of increased mobility and force on the tip of a straight elevator. The progress of dental treatments and surgeries is hard to anticipate, even if a thorough exam has been performed and high quality radiographs have been taken. It is therefore very important to know alternative ways to perform dental procedures. If necessary, transbuccal surgery can be performed in the field or in a clinic. The main risk of this procedure is the possibility of damaging the facial nerve, blood vessels or the parotid duct. Therefore anatomical orientation is very important to minimize the risk of injuring important structures.

References and Footnotes


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Surgical Extraction of Mandibular Cheek Teeth via Alveolar Bone Removal

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Introduction

Pathology associated with equine cheek teeth has been well documented by many research veterinarians and scientists from around the world. Dental fractures leading to significant crown loss and pulp exposure, apical infection, periodontal disease, dental malformation, supernumerary teeth, and maloccluded teeth are all potential pathologies that would necessitate extraction of a cheek tooth. Patient age and health, severity of disease, tooth positioning, severity of clinical signs, and owners’ financial and physical capabilities all play a role in determining if extraction is the best therapeutic option. Extraction of equine cheek teeth, especially of those that are not already mobile, is a demanding undertaking for both horse and veterinarian, and it should be undertaken with serious thought, preparation, and conviction. Before attempting any extraction proper sedation, analgesia, visualization, equipment, and assistant help should be ready for use. Although we all plan for the best possible outcome, the veterinarian undertaking the extraction should also be able to deal with any complication that arises as a result of the procedure however minor or major. With this in mind, the following extraction technique should only be undertaken by diplomates of the surgical and dental colleges, residents of specialty training programs, and general practitioners who have had extensive training in dental and surgical techniques. It is presented at the Focus to offer the general practitioner another option for dental extraction if referral to a specialist is an option.

In all published studies to date, intraoral extraction of teeth has provided the highest success rate and the lowest complication rate of any extraction technique; therefore, intraoral extraction of cheek teeth in the horse should always be considered prior to surgical extraction options. The author presents this extraction technique as an excellent option for all mandibular cheek teeth where other extraction techniques would prove impossible or less ideal for the diseased tooth and horse. This technique has been used for older maxillary premolars as well when intraoral extraction and/or repulsion were unsuccessful or impractical. The fact that there are so many different approaches to the extraction of equine cheek teeth highlights that no one technique is appropriate for every case and that the more techniques in which a practitioner becomes skilled improves the possible outcome for the horse. Indications for this procedure are loss or severe damage to clinical crown, crown-root fractures, apical infection of young teeth, impacted teeth, open-mouth restriction, very small patient size, radicular/odontogenic cyst formation, and dental malformation.

Materials and Methods

**An in-depth knowledge of equine maxillofacial and dental anatomy is paramount to perform this surgical procedure successfully**
This procedure is performed in as sterile a manner as possible.

**Equipment List:**

- Basic surgery tray (scalpel, forceps, metzenbaum and mayo scissors, needle driver, hemostats, etc)
- High-quality surgical grade headlamp and eye protection
- Dental elevators (winged elevator sizes 7mm or 8mm – Miltex)
- Long-handled small animal molar extraction forceps
- Lane’s bone holding forceps (13”)
- Periosteal elevator (Selden)
- Hohman retractor (20 mm)
- Blunt Weitlaner retractors (6.5 inch)
- Suction unit with thin, long suction tips
- Mini Lambotte osteotome (8 mm) with small mallet
- Pneumatic high-speed surgical drill with assistant irrigation
- Round carbide bur (4mm or 6mm)
- Round diamond bur (4mm or 6 mm) – OPTIONAL
- Bone curettes – straight and curved
- Polyvinyl siloxane impression material
- Routine closure material (Monocryl, PDS, Nylon, staples, etc.)

**Procedure for Mandibular Cheek Teeth:**

1. Do a complete oral exam and provide intraoral dental treatments as necessary.
2. Acquire preoperative radiographs to ensure the appropriate tooth for extraction and to evaluate regional and dental anatomy/pathology.
3. Place the horse under general anesthesia. Recently, a few cases have been performed standing with a CRI, but this is not recommended for veterinarians inexperienced with this technique.
4. A regional nerve block is performed, and the surgical site is clipped and aseptically prepped.
5. A small sterile marker or scalpel blade is used to mark the skin. The points marked are palpated intraorally:
   a. the junction of the buccal mucosa and the alveolar mucosa (vestibule) adjacent to the tooth to be extracted
   b. the clinical crown of the tooth to be extracted
6. The site is appropriately draped.
7. The skin incision is placed directly over the tooth to be extracted.
   a. If the tooth to be extracted is a mandibular premolar, a curvilinear incision extending in a rostrocaudal direction with the base oriented apically is created. The most ventral portion of the incision is placed directly over the tooth midway between the vestibule (previously marked) and the root apices of the tooth.
   b. If the tooth to be extracted is a mandibular molar, a straight incision running in a dorsoventral direction is created. This incision will be slightly tilted in the
rostrodorsal to caudoventral plane to mimic the angle of the tooth in the mandible. The incision runs from just ventral to the vestibule to the region of the root apices.

c. The reason for centering the incision ventral to the vestibule is to avoid penetration into the oral cavity via the cheek.

d. Avoid involvement of major regional anatomy (vessels, nerves, venous plexus, parotid duct, etc.) in the incision.

8. Carefully dissect through facial anatomy in routine fashion providing hemostasis during progression until the periosteum of the bone is encountered.

9. Incise and elevate the periosteum. The Selden periosteal elevator is excellent for this task. The periosteum should be elevated from the root apices to the attached gingiva of the tooth to be extracted.

   a. When the elevator pushes up against the gingival margin, gently but firmly elevate the gingiva off the bone to allow access to the oral cavity. To elevate the gingiva cleanly (without tears) follow the contour of the alveolar crest to the clinical crown.

   b. The gingival opening is extended rostral and caudal so the mesial and distal aspects of the tooth to be extracted are visualized. This will allow for confirmation of the position of the diseased tooth.

   c. Use the Hohman retractor to dorsally retract tissue and the Weitlaners to retract in the rostrocaudal direction.

   d. The alveolar bone plate overlying the diseased tooth should now be clearly visible.

10. A high-speed surgical drill with a carbide bur and irrigation is used to carefully and precisely remove the alveolar bone plate.

   a. Work in a dorsal to ventral direction, starting at the clinical crown, using the periodontal ligament as the landmark for drilling. The periodontal ligament will appear as a bright red surface.

   b. Clearly expose the most mesial and distal aspects of the reserve crown.

      i. ALWAYS LET THE TOOTH GUIDE THE DRILL.

      ii. NEVER GUESS WHERE TO DRILL.

   c. Suction is critical at this point for accurate drilling and visualization.

   d. Avoid drilling the clinical crown, reserve crown, and alveolar bone of the adjacent teeth.

   e. Remove the alveolar bone plate to the level of the furcation of the roots.

   f. A rectangular region of bone removal should result.

11. Section the diseased tooth.

   a. Using the drill, make a V-cut into the tooth from the clinical crown ventral to the furcation. The V allows for visualization at the bottom of the cut.

   b. Do not cut past the lingual periodontal ligament. The periodontal ligament will appear as a bright red surface after cutting through white tooth.

   c. When drilling the clinical crown avoid cutting the tongue by ensuring its placement on the opposite side of the mouth.

   d. Once the tooth is sectioned longitudinally, test the tooth fragments for mobility with dental elevation. If no mobility is detected, section the reserve crown in a mesiodistal manner. Now four fragments will be available for elevation.

12. Elevate the dental fragments.
a. The dental elevators are used to elevate these fragments.
b. If little progress is made, gently and superficially drive a Mini Lambotte osteotome into the periodontal ligament space. This will cause the fragments to collapse into the alveolus with minimal force.

13. Remove fragments from alveolus with small animal molar extraction forceps or Lane’s bone holding forceps.
   a. Pull tooth fragments from alveolus with coronally directed force. Do not lever the fragments in a side-to-side direction as this may cause them to break (especially the roots).

14. Thoroughly debride and flush the alveolus.
   a. Debride with caution in the region of the root apices as pathology may have exposed/involved the mandibular artery and nerve.
   b. Debride the fistula if present.

15. Smooth the bone margins with a round diamond bur (preferred) or carbide bur.

16. Take an intra-operative radiograph to ensure all dental and pathologic material has been removed.

17. Place polyvinyl siloxane impression material in dorsal third of alveolus.
   a. Packing material is placed intraorally while surgeon uses gauze to prevent material from migrating into alveolus ventrally.
   b. Packing material is molded flush to buccal bone margin and dorsal crestal bone. The gingiva should curl over edges of packing intraorally.
   c. Ensure no lipping of the packing material outside of the alveolus.

18. Close the surgical site in a routine manner. In the majority of cases, no drain is placed.

19. Thoroughly rinse oral cavity.

20. Apply a facial pressure wrap to minimize swelling. Remove in 3 days.

21. Recover the patient.

22. Provide post-operative pain management and antibiotics as needed.

23. Check the extraction site at days 2, 10, and 30 postoperatively.

24. Remove packing at the 30-day recheck.

**Discussion**

The term buccotomy for the described technique has been avoided, as the definition of buccotomy is “a surgical incision through the cheek to gain access to an intraoral procedure”. The incisions described are not made into the cheek proper but the tissue overlying the alveolar bone, and the incision gains access to the mandibular and maxillary bone where the bulk of the procedure is performed. Entrance into the oral cavity is a secondary effect of the procedure, not the sole purpose for it. This distinction though minor is important as it changes the nature of significant adjacent regional anatomy and the need to provide as aseptic a working field as possible.

Multiple studies have been reported on the efficacy and complications associated with “a buccotomy”. All of these studies should not be compared equally as the surgical technique in each paper is different in either major or minor ways; therefore, a discerning reader needs to closely read the materials and methods to know exactly what procedure is being reported on. A recent paper[^4], does a very good job of summarizing the last 2 decades of research in this area.[^4]
Recently, there have been two significant studies that have reported and evaluated the success of surgical procedures similar to the one detailed. One study used a true buccotomy to intraorally elevate gingiva and alveolar mucosa to expose the alveolar bone plate, which was removed by chisel. The second utilized a similar approach to the alveolar bone plate and with fluoroscopic guidance located the mesial and distal aspect of the tooth. An osteotome or bur was used to create a bone window onto the tooth, which was sectioned similarly. Apical fragments were elevated and coronal fragments were repulsed into the oral cavity. The main point of developing the technique above was to use the strengths of those procedures while improving upon their weaknesses. Though a similar retrospective study evaluating this technique has not been published, cases are being accumulated to produce such a study in the future. The main innovation provided by this technique is the use of a high-speed drill to carelessly and precisely remove the alveolar bone plate to allow for complete and acute tooth sectioning and fragment extraction with minimal to no trauma on adjacent teeth and minimal use of concussive forces. In addition, procedural times are usually shorter for the extraction of young teeth than traditional intraoral techniques.

Operative and postoperative complications encountered during this surgery were osseous bleeding in the region of the root apices, temporary partial paralysis of the ipsilateral buccal nerve, surgical site infection, and displacement of the packing material. Osseous bleeding though bothersome was never significant, and bleeding was easily controlled with the application of bone wax. Temporary paralysis of the buccal nerve was associated more with postoperative swelling than nerve damage during surgery. The lip was always checked for innervation and function following recovery from anesthesia. Prior to the author’s routine application of pressure wraps, it was found that partial paralysis would develop within 12-24 hours postoperative. Use of the pressure wrap for three days following surgery drastically reduced the number of cases with this complication. All horses that developed lip paralysis secondary to swelling resolved within 1-6 weeks postoperative. A small number of horses developed mild surgical site infections that were managed successfully with routine wound care and antibiotics. Finally, only two alveolar plugs displaced. One settled roughly 2 cm ventral to the alveolar ridge and the other was ejected into the oral cavity. Both were replaced with minimal effort and retained until removal. Additional possible complications not encountered by the author are laceration of the mandibular artery, destruction of major regional arteries, veins, and nerves, laceration of parotid duct, tongue laceration, mandibular fracture, damage to adjacent teeth, and displacement of packing into irretrievable position. With good surgical techniques, experienced drill skills, careful planning, and patience the author believes all of these possible complications can be avoided.

In conclusion, surgical extraction of equine cheek teeth especially on the mandible can be performed in a very precise, controlled manner that has the potential to reduce the number of operative complications experienced by surgeons and dentists in the past.

References


Dental Repulsion

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Take Home Message

When diseased teeth cannot be extracted through the oral approach, tooth repulsion after a trephination or sinusotomy should be considered. Equine dental repulsion has historically been performed with the horse in lateral recumbency under general anesthesia. Repulsion of fractured teeth or root tip fragments in the standing sedated horse has gained credibility in recent years. Meticulous attention to detail during every phase of the surgery will keep complications to a minimum.

Introduction

Retrograde removal of a tooth by repulsion became fashionable during the 20th Century at a time when safe general anesthesia of the horse became possible.

The technique has changed little over the past 50-100 years.1-3 Repulsion of diseased teeth remains a commonly performed surgical procedure in equine practice despite the widely reported high incidence of complications associated with it and its mechanical inefficiency.4-9 While most equine cheek teeth can be removed by extraction through the oral approach in the standing sedated horse, tooth repulsion is a surgical alternative for removing diseased teeth with shortened or broken crowns or when intraoral extraction has resulted in root tip fracture.10,11 The use of elevators, introduced through a direct oral or buccal approach to remove these damaged teeth, has been successful.12,13 The lateral buccotomy approach may be indicated for chronically infected teeth where an abundance of reactive cement has developed around the infected apex and adjacent reserve crown, precluding the passage of the affected tooth into the oral cavity through the narrower alveolar socket.14-17

Regardless of what surgical technique of exodontia is used, the basic principles of tooth removal should be followed:

1. Sever the gingival attachment to obtain adequate access to disrupt the periodontium.
2. Create an unimpeded pathway for removal of the tooth.
3. Use controlled force to remove the tooth from its socket.18

Attempting to disrupt some of the periodontium, using extraction forceps per os, before embarking on a surgical course of dental extraction via retrograde repulsion, is good practice. To repulse a tooth, the tooth’s apex must be exposed in order to allow correct alignment of the dental punch on the apex of the tooth. Thus, force can be delivered along the natural eruption
pathway of the tooth. The apex of a cheek tooth is exposed by creating an osteotomy in the overlying mandible or maxillary bone, using a trephine, drill bit, oscillating bone saw, or osteotome.\textsuperscript{10,19} For small root fragments, a Steinmen pin has been used to create the osteotomy to allow punching the fragment into the oral cavity.\textsuperscript{11,20}

While a tooth can be repelled with the standing horse sedated and the surgical site desensitized using regional anesthesia, a cheek tooth is usually repulsed with the horse under general anesthesia. The anesthetized horse is placed in lateral recumbency with the affected side of the head uppermost.\textsuperscript{19,20} When extraction is to be performed with the horse anesthetized, a cuffed endotracheal or nasotracheal tube should be inserted into the trachea to prevent inhalation of fluid. The tube should be large enough to permit adequate ventilation, but small enough to provide sufficient space to allow a hand or forceps in the mouth for extraction. Anesthetizing the arcade of the affected tooth with a regional nerve block after the horse is anesthetized allows surgery to be performed with the horse in a lighter plane of anesthesia and provides analgesia during the immediate postoperative period.\textsuperscript{10,21}

A full-mouth speculum (e.g., a Guenther or Stubbs oral speculum) is inserted to provide safe access to the oral cavity. The tooth can be loosened prior to general anesthesia or after the horse is anesthetized, but before it is prepared for surgery. The gingiva should be separated from the buccal and lingual or palatine aspects of the tooth to the level of the marginal bone. With elevation, the gingiva is not avulsed as the tooth is repulsed. Use of a long-handled, right-angled periodontal elevator is appropriate. A molar spreader and extraction forceps can be used to loosen the tooth in the socket if there is exposed crown with which to work.\textsuperscript{22}

**Surgical Approach to the Dental Apex**

The osteotomy must be created precisely over the tooth’s apex to avoid damage to an adjacent, healthy tooth. The location of the apex varies according to the tooth involved and the age of the horse. The optimum site of apical exposure can be roughly identified using several techniques.\textsuperscript{10,11} Rather than approximating the location of the tooth’s apex, the exact site of the apex of the diseased tooth can be identified radiographically by placing radio-opaque markers, such as skin staples, in the region estimated to be near the tooth’s apex or by placing a blunt metallic probe into a discharging tract at the tooth’s apex. The primary X-ray beam must be approximately perpendicular to the longitudinal and transverse axes of the head. Even slight deviation of the beam from a plane perpendicular to these axes markedly distorts the image, which could result in parallax distortion and inaccurate identification of the osteotomy site. Multiple views should be taken until the precise position for the surgical approach is identified with confidence.

Horses radiographed in lateral recumbency will have the cassette on the down side. This is the opposite side of the head from the affected tooth and different than the standing preoperative films. This must be taken into consideration when interpreting intraoperative films for punch placement and immediate postoperative films for evaluating the dental alveolus.\textsuperscript{23}
The maxillary or mandibular bone overlying the apex can be exposed for osteotomy through a straight, longitudinal skin incision, approximately 5–7 cm long, or through a dorsally or ventrally directed cutaneous flap. A straight skin incision extends through the periosteum, which is reflected, using a periosteal elevator, to expose bone for trephination. The curvilinear or rectangular incision of a cutaneous flap extends through the subcutaneous tissue. After elevating the cutaneous flap, a straight longitudinal incision is created in the subcutaneous tissue and periosteum, which are then reflected. Reflecting periosteum, rather than removing it, avoids damage to nerves and vessels that overly it. Using this approach, periosteum is spared and healing of the osteotomy proceeds more rapidly.

When exposing bone overlying the apex of a maxillary premolar (Triadan 106–108 or 206–208), care should be taken to avoid damaging the infraorbital nerve and facial artery and vein, which lie in close proximity to the osteotomy site. To avoid damaging the infraorbital nerve when removing a maxillary 3rd (Triadan 107 or 207) or 4th (Triadan 108 or 208) premolar, the dorsal aspect of the osteotomy should be ventral to the infraorbital foramen. The apex of any one of the three maxillary premolars is exposed by removing the external lamina of the maxilla overlying it, usually with a trephine.

The apices of the maxillary molars (Triadan 109–111 or 209–211) reside within the paranasal sinuses and can be exposed through a trephine hole or through an osteoplastic flap into the paranasal sinuses.24

Regardless of where the apex of the tooth is determined to reside, the osteotomy created to expose the apex of a maxillary cheek tooth should be ventral to an imaginary line that marks the course of the nasolacrimal duct. This duct courses between the medial canthus of the eye and a point slightly dorsal and rostral to the infraorbital foramen. The dorsal aspect of the osteotomy should be close to this line if the horse is less than 8 years old because the cheek teeth of this aged horse have undergone little attrition of length. The ventral aspect of the osteotomy should be close to the facial crest if the horse is old.

The mandibular cheek teeth of young horses often extend to the ventral border of the mandible. Therefore, if the horse is young, the ventral aspect of the osteotomy should also extend to the ventral border of the mandible. When exposing bone overlying the apex of the mandibular 1st molar (Triadan 309 or 409), care should be taken to avoid damaging the facial artery and vein and the parotid salivary duct, which cross the lateral surface of the mandible along the rostral border of the masseter muscle close to the site of osteotomy. Reflecting these structures away from the site of trephination may be necessary.

After incising and reflecting the periosteum, the apex of the tooth is exposed through an osteotomy, which is commonly created using a 1.5- to 2-cm (1/2- to 3/4-inch) diameter Galt trephine or a 0.95-cm to 2.7-cm (3/8- to 1/2-in) drill bit rotated in a hand drill or by hand. To create a hole in the external lamina of a maxilla or the mandible with a trephine, the center-pin of the trephine is extended and seated perpendicular to the exposed bone. The trephine is rotated to and fro until the center-pin penetrates the bone and the barrel of the trephine cuts a circular groove in the bone. The center-pin is retracted or removed, and the circular osteotomy is
continued until the disc of bone is completely transected. If the bone is sclerotic and thickened, the transected disc of bone may not be removed with the barrel of the trephine. It can be pried from its attachments with a bone gouge.

The apex of the tooth is completely exposed by removing overlying cancellous alveolar bone with a bone curette. To avoid damaging an adjacent, healthy tooth, the entire apex of the tooth should be exposed, and both proximal surfaces of the diseased tooth identified before the tooth is repulsed into the oral cavity. Suction is helpful at this point in the procedure to aid visibility, which is usually obscured by constant capillary bleeding. If the trephine hole has not adequately exposed the apex of the tooth, the hole can be enlarged using a bone rongeur, a bone gouge and mallet or high speed drill and burr.

The maxillary 1st or 2nd molar (Triadan 09 or 10) can be removed through a trephine hole created into the paranasal sinuses over the apex of the tooth. To repulse the maxillary 1st molar (Triadan 109 or 209), which is the most commonly diseased maxillary tooth (located in the rostral maxillary sinus), the trephine hole is usually centered at a point midway between the rostral end of the facial crest and a point on the facial crest at the level of the medial canthus of the eye, 1 cm ventral to an imaginary line drawn between the infraorbital foramen and the medial canthus of the eye.

To remove the 2nd maxillary molar (Triadan 110 or 210), the trephine hole is centered more caudally over the caudal maxillary sinus, rostroventral to the ventral orbital rim. However, the site varies between horses and is affected by the age of the horse. Selection of the optimal site for trephination should be guided by radiographic examination. One author suggests an approach to the 2nd maxillary molar that involves creating three trephine holes (the triple trephine technique). Using this approach, one hole is created dorsomedial to the medial canthus of eye for placement of the punch on the apex of the tooth. A second hole, created ventrorostral to the medial canthus, allows the punch to be guided onto the apex of the tooth and allows the alveolus to be inspected postoperatively. The third hole, created at the angle formed by the orbit and the facial crest provides a portal for placing a catheter into the caudal maxillary sinus for postoperative lavage of the paranasal sinuses. Alternatively, reasonable access to the 2nd maxillary molar of mature horses (>8 years old) can be gained through either a maxillary or frontonasal, osteoplastic flap. To create a dorsally hinged, osteoplastic maxillary flap, a three-sided incision through the skin, subcutis, and periosteum is created within the confines of the boundaries of the rostral and caudal maxillary sinus. The osteoplastic, maxillary flap provides the operator opportunity to visually examine a large extent of the paranasal sinuses and permits manipulation of dental instruments within the sinuses.

Access to the apical aspect of the alveolus after surgery is easier if the apex of the tooth was accessed through a trephine hole, provided that the skin over the hole is left unsutured to heal by second intention. If the cutaneous incision over the trephine hole is sutured or stapled, the incision can be re-opened to inspect the apical end of the alveolus and then re-sutured or stapled when access is no longer required.
A disadvantage to creating an osteoplastic maxillary flap, rather than a trephine hole to repulse a maxillary molar, is that unless the flap is reopened, access to the apical aspect of the alveolus is no longer accessible to monitor healing of the alveolus or to curette the alveolus, should the need arise. A recent study has shown it beneficial to reopen the sinus flap 24-48 hours after the initial surgery to explore and debride the sinus. If the apex of the tooth was accessed through an osteoplastic flap into the sinuses, the apical end of the alveolus can be inspected endoscopically through the trephine hole created to provide a port for lavage of the sinuses. Removal of inspissated pus and creating a hole into the nasal cavity to allow ventral sinus drainage may be indicated in select cases.

Removing a mandibular 2nd (Triadan 310 or 410) or 3rd (Triadan 311 or 411) molar is particularly difficult because the bone over the apices of these teeth is covered by the masseter muscle and because the apices of these teeth are distant from the ventral border of the mandible, even in young horses. To remove one of these teeth, and sometimes the mandibular 1st molar (Triadan 309 or 409), the ventral aponeurosis of the masseter muscle is incised so that the muscle can be reflected dorsally to expose the underlying thin lateral lamina of the mandible overlying the apex of the tooth.

To elevate the masseter muscle, skin is incised along the ventrocaudal border of the mandible, ventral to the masseter muscle, from the angle of the mandible rostrally, taking care to avoid the parotid salivary duct and facial artery and vein where they cross the mandible at the rostral aspect of the masseter muscle. The incision is extended through the insertion of the muscle, and the muscle and the periosteum to which the muscle is attached are elevated to expose the external lamina of the mandible. The site for osteotomy to expose the apex of the diseased tooth is then located using intraoperative radiographs.

The lateral plate of bone overlying the apex of the 3rd mandibular molar (Triadan 311 or 411) can also be exposed through an incision in the masseter muscle. Exposure to the dental apex and positioning the dental punch is more difficult through this approach.

**Repulsion Procedure**

After the apex of a diseased cheek tooth has been exposed the tooth is repulsed into the oral cavity by striking a dental punch applied to the apex of the tooth and aligned in the direction of the tooth’s path of eruption. Confirming the position of the punch radiographically ensures that the punch is properly aligned. Failure to align the punch correctly may result in damage to a neighboring tooth, the palatine bone, if the tooth is maxillary, or to the internal or external lamina of the mandible, if the tooth is mandibular. When the punch is aligned obliquely to the long axis of the tooth, more force is required to repulse the tooth because the periodontium is not disrupted as efficiently as when the punch is properly aligned. The extra force required is more likely to result in bony or dental sequestra. The reserve crowns of the cheek teeth curve axially in a coronal to apical direction, and because the mandibular and infraorbital nerves lie slightly medial to the center of the teeth, applying the punch slightly lateral to the central axis of the tooth reduces the risk of damaging these nerves.
The apex of the tooth can also be exposed through a frontonasal or maxillary osteoplastic flap if it resides completely within the maxillary sinuses (i.e., the maxillary molars, Triadan 109-110 and 209-210. Because the apex of the maxillary 3rd molar (Triadan 111 or 211) lies beneath the eye, it must be exposed either through a trephine hole in the frontal bone or through a frontonasal, osteoplastic flap. The punch is inserted through the frontomaxillary aperture into the caudal maxillary sinus to engage the apex of this tooth, which lies ventral to the infraorbital canal. Aligning a dental punch along the eruption path of a maxillary 3rd molar is difficult because of the tooth’s position below the orbit and its caudal curvature. Using an off-set (i.e., a double-curved) punch to repel the maxillary 3rd molar is helpful. Obtaining proper alignment between the punch and tooth without damaging the infraorbital canal is often difficult using a straight or curved punch.

An off-set punch is often easier to properly align than is a straight or angled punch, but two or three off-set punches, each with a different length of shaft, may be required to completely repulse the tooth. Continuing to strike the punch with the mallet after the horizontal arm of the off-set punch has contacted bone at the margin of the trephine hole results in damage to the bone and is ineffective in repulsing the tooth.

Inserting a hand in the horse’s mouth and palpating the clinical crown of the affected tooth, the operator or a non-scrubbed assistant can determine if the punch is properly aligned and seated on the tooth intended to be removed. The operator or assistant can detect percussion transmitted through the tooth and movement of the tooth.

Striking the punch when it is in contact with the tooth produces a higher pitched sound than when the punch is struck when in contact with bone. A better feel for proper alignment of the punch can be appreciated if the operator with the hand in the mouth, also controls the alignment of the punch with his or her other hand. This should be accomplished only while a trustworthy, second operator wields the mallet. Numerous, vigorous blows with the mallet are usually required to dislodge the tooth from its alveolar attachments. When movement of the tooth can be felt with the hand in the mouth, the force of the blows to the punch is decreased.

A long tooth of a young horse, especially a tooth located caudally on the arcade, must often be deviated axially with an extraction forceps as the tooth is repulsed so that it does not become impinged by the opposing arcade. Transverse sectioning of a partially repulsed tooth to facilitate its repulsion is awkward to perform and risks creating subgingival dental fragments. Despite being widely advocated by others, this is seldom if never necessary. Wedged teeth can usually be maneuvered after minor profiling using a rotary burr. After the tooth has been repulsed, the operator must re-glove before proceeding with the surgery.

**Post-Repulsion Socket and Wound Care**

The tooth is usually fragmented while being repulsed and it should be examined to determine if pieces are missing. The alveolus should be inspected visually and digitally. Dental fragments still attached to the alveolus may be difficult to detect. The tooth of a young horse is more brittle than that of an old horse. Therefore, it is more likely to be fragmented. After the alveolus is
curetted, irrigated, suctioned, and dried, it should be examined radiographically to detect osseous or dental fragments that may remain within it. A ventrodorsal radiographic projection of the alveolus, obtained with the cassette in a sterile sleeve, provides a good view of the vacated alveolus. Pulling the mandible laterally may allow a view of the entire vacated alveolus unobstructed by superimposition of teeth in the opposing arcade.

The alveolus is sealed from the oral side using polysiloxane putty, bone wax, polymethacrylate (PMMA) bone cement, gutta percha, or Plaster of Paris to prevent feed and saliva from contaminating the alveolus. Plugs of PMMA provide the best long-term security against alveolar contamination. The plug should fill no more than the coronal third of the alveolus so that the bulk of the alveolus is able to fill first with a blood clot and then with granulation tissue. The plug should not extend more than a few mm past the gingiva, but should be long enough to remove with a forceps. A plug that protrudes much past the gingiva is prone to loosening by the tongue or from mastication.

Care should be taken when molding a plug for the alveolus to avoid forming sharp projections that can cause discomfort to the horse by traumatizing the tongue or gingiva. Care should be taken to ensure that the plug’s apical end is narrower than its coronal end and that the plug fits tightly within the alveolus. The plug should be examined after the horse recovers from anesthesia, using digital palpation, to ensure that it is seated tightly within the alveolus. A loose plug should be removed with extraction forceps and replaced after irrigating debris from the alveolus. This can usually be accomplished with the horse sedated and its mouth held open with an oral speculum.

The alveoli of old horses are shallow and care must be taken to avoid over-packing the alveolus. The pack placed into the alveolus of an old horse should be shallow so that granulation tissue can form unimpeded through most of the alveolus. An alveolar plug that extends into a maxillary sinus results in a persistent oroantral fistula. Overpacking the alveolus can be avoided by packing gauze swabs into the apical end of the alveolus, and removing them after the alveolar plug, placed orally into the coronal aspect of the alveolus, has set. If the skin incision is to be sutured, it should be sutured only after the plug has been inserted, so that the depth to which the plug has been packed in the alveolus can be determined accurately. If the incision is to be left open, rolled gauze impregnated with a dilute solution of povidone-iodine can be packed concertina fashion into the apical aspect of the alveolus, prior to inserting the plug orally into the coronal aspect of the alveolus. The gauze can then be gradually removed over the next 4–5 days.

If maintaining the implant in the alveolus is likely to be difficult, such as when the tooth removed was the 1st cheek tooth (2nd premolar, Triadan 06), the plug can be molded around a small section of screen to which a loop of stainless steel wire has been attached. The ends of the wire loop are inserted through the oral entrance to the alveolus and exited through the osteotomy and a cutaneous stab incision created adjacent to the site of osteotomy. The plug and screen embedded within it are pulled into the oral aspect of the alveolus, and the ends of the wire loop are secured under tension over a gauze roll. The gauze roll is changed when it becomes soiled. A three loop spring wire has also been used successfully to secure a plug in the dental socket.29
A straight skin incision over the site of osteotomy is often left open to heal by second intention because contamination of the surgical site with oral pathogens is inevitable. Leaving the incision unsutured allows the alveolus to be inspected and loose, osseous or dental debris retained within the alveolus to be easily retrieved. The alveolus can be irrigated and monitored daily, visually and by palpation, for healing through the open incision. The leakage of saliva contaminated with ingesta from the incision or escape of fluid into the mouth during irrigation of the alveolus indicates that the alveolar plug should be replaced. Packing gauze swabs into the skin incision until the alveolus has filled with granulation tissue, usually at 2–3 weeks, prevents gross contamination of the surgery site from the environment.

If the skin incision at the osteotomy is to be sutured, the surgical site should be irrigated vigorously. If the likelihood of infection at the surgical site is high, a drain can be placed into the depths of the wound and exited through another small incision. The subcutaneous tissue is sutured with absorbable monofilament suture, and the skin incision is apposed with non-absorbable suture or staples. The inelastic periosteum holds sutures poorly and need not be sutured. Gauze swabs are placed over the incision and held in place with sutures or with adhesive elastic tape applied to the head in a figure-of-eight fashion to minimize swelling at the surgical site and to prevent the horse from mutilating the site. The head is generally left bandaged for at least 5 days. If the incision is sutured, it should be inspected periodically for signs of subcutaneous infection.

The incision should be opened if signs of infection, such as drainage through the incision, are observed. Granulation tissue surrounding the plug epithelializes within several weeks. The plug may eventually be lost spontaneously, but if not, it can be removed, usually at about 6-8 weeks after surgery, with the horse sedated. The portion of alveolus occupied by the plug fills completely with granulation tissue after the plug is removed. Permanent retention of a plug is desirable only when the horse is at increased risk of developing an oroantral fistula. If the plug is attached to a wire loop, both the plug and the wire must be removed. If the paranasal sinuses are to be lavaged after a maxillary molar has been repulsed, a 0.95-cm (3/8-inch) trephine hole, which is large enough to accommodate a 26- or 24-Fr Foley catheter, is created, through a straight cutaneous incision into the conchofrontal or caudal maxillary sinus through a small incision. A trephine hole into the conchofrontal sinus is created 2–3 cm medial to the medial canthus of the eye, and a trephine hole into the caudal maxillary sinus is created, through a straight incision, 1.5 cm ventral to the ventral rim of the eye. Warm, isotonic saline solution instilled into the sinuses through the Foley catheter exits the sinuses into the nasal cavity through the nasomaxillary aperture. The sinuses are lavaged for 1–7 days; the frequency and duration for which the sinuses are lavaged depends on the degree to which the sinuses were contaminated. The cutaneous incision over the osseous portal can be sutured or stapled after the catheter is removed, or the incision can be allowed to heal by second intention.

**Minimizing Complications of Tooth Removal**

The removal of a tooth or a number of teeth from a horse should not be approached casually. Reports on the incidence of complications that accompany cheek tooth removal range from a low level of 4 per cent for simple oral extractions in the older horse to as high as 47 per cent for repulsion of maxillary cheek teeth.6 Other studies have shown a 22 to 40 per cent rate of
Complications from traditional tooth repulsion.\textsuperscript{4,5} Complications can be divided into categories beginning with problems associated with restraint, general anesthesia, and long-term hospital care. Problems associated with the extraction itself include hemorrhage, removal of the wrong tooth, damage to structures adjacent to the tooth being removed (i.e. palatine artery, sinuses, infraorbital nerve, alveolar bone, jaw bone, adjacent teeth, nasolacrimal duct, parotid salivary duct and facial nerve).\textsuperscript{7,8}

Complications associated with wound healing can include wound dehiscence or persistent draining due to fistula formation, resulting from incomplete tooth removal, bone sequestrum, damage to alveolar plate of adjacent tooth, infected dental socket, packing breakdown, mucous membrane healing prior to wound granulation or a foreign body in the healing wound. Trephine holes and osteoplastic flaps can have problems with healing and leave a facial scar or facial fistula. Long-term complications can be associated with a misdiagnosis of the initial problem that can result in removal of a wrong or inappropriate tooth, leaving behind a tumor, infected sinus with inspissated pus or diseased tooth. Additionally, long-term consequences can occur with abnormal wear of opposing teeth and rostral or caudal drift of adjacent teeth that, over time, can lead to diastema, periodontal pockets and further dental disease.

The process of completely examining the masticatory system and careful surgical planning cannot be overemphasized. Routine dental occlusal adjustment and enamel point reduction should be performed prior to surgery. The equine dental surgeon must be well versed in the anatomy, physiology, embryological formation, and development of the hard and soft tissues of the equine masticatory system. The surgeon must be aware of age related changes in teeth and supporting structures and the impact age has on dental wear and disease. Finally, there must be good surgical support for anesthesia as well as intra-operative imaging (radiographs or fluoroscopy). Postoperative treatment and long-term follow-up care are critical to a desirable long-term prognosis.

Careful and complete examination of the equine patient will allow an accurate diagnosis of the dental problem and any associated medical conditions that could cause problems during restraint and anesthesia. A full series of radiographs should be performed on horses with mandibular or maxillary swellings or paranasal sinus disease. When available, scintigraphy, digital radiography, computerized tomography and MRI can be used to assist with diagnosis. Surgery should be planned with facilities and equipment adequate to support the patient. Prolonged periods of keeping the mouth open with a speculum or rough use of a speculum can also lead to postoperative pain and damage to muscles or to the temporomandibular joint. Special considerations need to be given to upper airway maintenance and lower airway protection from oral fluids and debris. Nasotracheal intubation or a tracheotomy tube may be necessary. Reports in the literature quote the average hospital stay after tooth repulsion to be 2 to 61 days (median 22 days) for maxillary teeth and 3 to 35 days (median 8 days) following mandibular tooth repulsion. Every effort should be made to minimize the patient’s postoperative stay thus reducing the chance of acquiring a nosocomial infection and shortening the ultimate recovery phase.

During the surgical procedure, hemorrhage is a concern from the very nature of the surgery. The nasal turbinates, oral mucosa and sinuses are very vascular. It has been recommended that
packing the nasal passages or sinuses is the most important factor in preventing postoperative blood loss. Infusion of balanced electrolyte solutions, hypertonic saline solutions and administration of dobutamine may be needed to maintain adequate blood pressure after severe blood loss. The decision to perform a whole blood transfusion should be made on the basis of mucous membrane color, capillary refill time, oxygen saturation, packed cell volume hemoglobin concentration and arterial blood pressure.30

Careful surgical planning and review of anatomy can reduce the chance of damaging structures that should be protected during surgery. The parotid salivary duct, palatine artery, nasolacrimal duct and facial nerves are structures to be considered when surgery is anticipated. Judicious use of intraoperative radiographs or fluoroscopy is indicated to avoid operative problems such as removal of the wrong tooth or damage to structures adjacent to the tooth being removed. These would include the palatine artery, mesial or distal alveolar bone and adjacent teeth. Additional radiographs taken after tooth removal are useful in confirming that the proper tooth was removed and the alveolus is clear of unattached pieces of bone, slivers of crown enamel, root fragments or cementomas.

Many factors can delay healing of the dental socket. In the normal course the vacant alveolus fills with a sterile hematoma. This blood clot, protected from oral contamination, is the framework for a vascularized bed of granulation tissue that migrates inward from the outside margins of the wound, filling the void left by the removed dental crown and roots. The mucosa of the oral cavity, paranasal sinus, nasal passage or skin adjacent to the wound migrates over the bed of granulation tissue and, along with wound contraction, covers the alveolus with a layer of epithelium to complete socket healing.

Many factors can delay or completely interrupt this healing process, causing long-term problems for the horse and in some cases the need for further corrective surgery. Persistent sinus tract formation is a common complaint following tooth removal. A sinus tract is a tubular ulcer that refuses to heal owing to the presence of a foreign body or dead tissue. A draining sinus is lined by granulation tissue and will heal rapidly once the offending material is removed. Sources of sinus formation can be pieces of avascular bone, dental fragments, dental packing materials, feed or debris from the oral cavity, avascular or infected nodules of cementum or any foreign body in the depth of the healing wound. Characteristically, a sinus will discharge purulent material, and then appear to heal. However, the infection or irritation persists and the sinus tract reforms periodically. Transient response is often seen following systemic antibiotic therapy.

The successful treatment of a sinus tract involves removing the cause of the irritation to allow the tract to heal spontaneously. The source of the sinus should be identified with plain and/or contrast radiographs and a complete examination of the involved area should be performed. Generally, it can be determined where the source of the sinus is likely to be and this area should be approached surgically via the most suitable route. Placement of drainage tubes or antibiotic impregnated beads of methylmethacrylate and protection of the surgical area from oral contamination can speed healing. Plugging the dental socket with bone cement has been shown to be superior in protecting the alveolus.31
A fistula is a similar non-healing wound connecting skin with a mucosal surface or one mucosal surface to another. In a fistula, the tract can be lined with granulation tissue, scar tissue or epithelium that has grown along it from either or both ends. Dental fistulae can form connecting the oral mucosa to the skin (orocutaneous), to the paranasal sinus (oroantral) or to the nasal mucosa (oronasal). The treatment of fistulae is usually complex and detailed anatomical reconstruction may be required. The epithelial tube lining a fistula must be completely removed to allow the defect to fill with granulation tissue. Cutaneous fistulae have been known to form over the paranasal sinuses after they have been opened by trephination or a sinus flap. Fistulae between the nasal passages and paranasal sinuses are not usually a concern and can be useful in some situations to allow better ventral drainage of the paranasal sinuses.

References


Restorative Dentistry in Horses

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Introduction

Restorative dentistry is the dental discipline concerned with the treatment, repair, and conservation of teeth broken down by trauma or decay. The goals of restorative dentistry include returning the diseased tooth to its original shape and function, preventing breakdown of the remaining tooth structure, protecting the pulp from thermal, mechanical, and bacterial insult, and creating an aesthetic tooth appearance.

Throughout recorded equine dental history, exodontia has been the primary treatment option for diseased teeth; however, the goal of dentistry is to preserve functional dentition in order to promote the general health, longevity, and productivity of the horse. Although equine veterinarians have practiced restorative dentistry for over 120 years, the introduction of less technique sensitive dental materials over the last 20 years has stimulated renewed interest in direct placement restorations.

While there are numerous anecdotal reports of restorative successes in equine patients, the peer reviewed literature is limited to only a few case reports. All of which should be viewed as biased according to the standards of evidence based medicine. Therefore, until the application of restorative materials in equine hypsodontic teeth have been scientifically evaluated, each practitioner must make treatment decisions based on his/her personal experiences and understanding of restorative principles.

Treatment Planning

Regardless of the disease etiology, the restoration of a tooth includes two equally important procedures: (1) cavity preparation and (2) selection and application of the restorative materials. Early diagnosis of a cavity, before the structural integrity of the tooth is compromised, facilitates for a favorable outcome. Treatment planning for any restoration must include radiographic evaluation of the affected tooth and its surrounding tissues. Radiographic evaluation of the diseased tooth includes evaluation of the pulp, the specific location of the lesion, and the depth and extent of the lesion. Radiographic findings consistent with pulp disease would indicate root canal therapy before tooth restoration. The location of the lesion on each specific tooth determines the forces that will be applied to the restoration. Restorations on the occlusal surface of a tooth must be designed to withstand compressive loading and wear; whereas, restorations on the proximal, vestibular and lingual aspects of the clinical crown might experience tension or bending stresses. Regardless of the present location of the lesion, all restorations have the potential for eventual occlusal wear due to hypsodontic tooth eruption; therefore, the strength and wear resistance of restorative materials must be considered during
material selection. The depth and extent of the lesion must be evaluated to determine the dental tissues involved in the lesion as well as the proper size and shape of the cavity preparation. Consideration of these factors will determine the required properties of the restorative materials needed to fill the cavity.

Cavity Preparation

Cavity preparation is the surgical operation involving the debridement of decayed or diseased dental tissues in order to shape the tooth to receive and retain the restorative material. The procedure is usually performed in the standing sedated horse, and local anesthesia should be provided if the lesion extends into the dentin. Instrumentation includes excavators and a high-speed water-cooled dental drill and burs. Regardless of the location of lesion, the operator must adhere to the following principles:

1. The cavity must be prepared so that all diseased and damaged dental tissues are removed without weakening the tooth’s structure.
2. The cavity is extended to prevent further decay or damage to the restoration.
   a. Removal of any unsupported or undermined dentin and enamel.
   b. The walls of the cavity are oriented perpendicular to the tooth surface.
3. The cavity is configured to facilitate filling, retention, and finishing of the restorative material.
   a. Dentinal undercutting for mechanically retained materials.
   b. Marginal beveling to increase the enamel surface bonding area.

Direct Placement Restorative Materials

The ideal restorative material would allow for conservative cavity preparation, be easy to apply, bond to the substrate (dental tissues), have the similar strength, thermal, and wear characteristic to the tooth, and be the same color as the tooth. No material has all of these ideal characteristics; therefore, a material, or combination of materials, must be selected based on its specific advantages in a specific situation. Three basic groups of restorative materials are used in veterinary dentistry: Amalgam, Glass Ionomers, and Resin Composites. Amalgam has lost popularity in both human and veterinary dentistry, and will not be discussed.

The following is a general discussion of clinical properties and applications of the different categories of dental restorative materials. While the materials within each category are similar, each product has unique properties, handling characteristics, and an application protocol. To optimize the clinical properties of any material, the manufacturer’s instructions for storage, mixing, and application must be followed exactly.

Types of Bonding

To select and apply the appropriate restorative materials, practitioners must be familiar with the bonding mechanism of each material.
1. **Mechanical Retention**: Nonadhesive bonding where the dental material infiltrates the surface irregularities of the dental tissue and cures to interlock with the dental tissue. **All restorative materials exhibit mechanical bonding.**

   A. **Macromechanical Retention** – involves instrumented undercuts (retention grooves) in the dental tissues (usually dentin).

   B. **Micromechanical Retention** – involves surface preparation (acid etching) and the use of bonding agents that microscopically interlock in the enamel porosities, dentinal tubules, and other microscopic surface irregularities. The bonding mechanism with **resin composite systems**.

2. **Chemical Bonding** – **Glass ionomer** forms a chemical crystal bond between the carboxyl groups in the polyacid of the cement and the calcium ions of the apatite crystals in the enamel and dentin.

**Bases and Liners**

Cavity preparations, in which less than 2 mm of dentin remains between the pulpar wall and the pulp (indirect pulp exposure), require the application of a pulp protecting material. Cavity liners and bases are used to protect the pulp.

*Cavity liners* are nonirritating materials which are placed in a thin layer to protect the pulp and decrease dentinal sensitivity. They provide no thermal or mechanical protection and are *inadequate as a sole protective medium*. Calcium hydroxide (**CaOH**) is the most popular liner. CaOH is supplied as a powder or as commercially prepared pastes. The powder can be applied directly into a pulp canal or mixed into a paste with water, saline, or anesthetics. The strong alkalinity (pH 12.5 when mixed with saline) of CaOH is bactericidal, neutralizes acids, and induces reparative dentin formation. CaOH will dissolve if contaminated with oral fluids and must be covered by an insoluble restorative material.

*Cavity bases* are used in deep cavities to provide structural support for the final restoration and chemical and thermal protection of the pulp. Dental cements are typically used as bases. Glass Ionomer (**GI**) cement is currently the most popular base material.

**Glass Ionomer Cements**

Glass ionomer (**GI**) cements are a group of materials which *chemically bond* to dentin and enamel. Bonding to cementum has not been investigated. GIs are formulated for many dental applications (see Classifications of GI Cements), but in veterinary medicine GIs are primarily used as bases and liners under composite restorations to protect the pulp, to minimize thermal conduction, and to augment marginal sealing. This application is commonly referred to as the “sandwich technique.” GIs are relatively biocompatible with pulp. The chemical bonding of GIs allows for conservative cavity preparation and placement into moist fields, and GIs have shown clinical success when placed in incompletely debrided cavities (Atraumatic Restorative Treatment). The unique property of GIs is the release of high levels of fluoride ions over the life of the restoration which is known to strengthen enamel, decrease dentin sensitivity, and provide an antibacterial and cariostatic effect to the surrounding tissues. Since GIs have poor mechanical properties (hardness, fracture strength, and wear resistance), they are inappropriate for most
equine restorative applications. GIs are technique sensitive during preparation and placement and must be mixed and applied exactly according to the manufacturer’s specifications for handling and working time. To improve the mechanical properties and handling characteristic, resins and other admixes are being added to GIs; however, most of these products lack clinical validation.

Classifications of Glass Ionomer Cements

- **Type I:** Luting cements used to bond crowns and orthodontic appliances.
- **Type II:** Restorative materials.
- **Type III:** Bases and liners used under composite materials.
- **Type IV:** Admixes, Light-curing bases and liners.

The Basic Technique for Glass Ionomer Restoration

1) The tooth and cavity preparation are cleaned with non-fluoride, flour pumice.
2) If the manufacturer recommends or if increased bonding strength is required, condition the cavity with polyacrylic acid. (see Acid Etch Technique) Evidence-based dentistry protocols support this step.
3) Mix, or activate (encapsulated GI), exactly according to the manufacturer’s instruction. Remove one level scoop of powder and place it on a mixing pad. Divide the powder into three to four aliquots. Dispense the liquid next to the first aliquot and rapidly mix with a mixing spatula. Continue by drawing each aliquot into the liquid until the material is thoroughly mixed. The typical mixing time is approximately 30 seconds; however, mixing on a chilled surface extends the working time. The prepared material should have a uniform, tacky, glossy liquid consistency.
4) Apply the GI to the restoration with a plastic instrument or a compule syringe. In vertical restorations a mylar strip is usually required to hold the material in place. The initial setting time for GIs is approximately 4 minutes, during which time the material can be manipulated; however, overworking the material should be avoided.
5) The GI must be protected from contamination and drying during the initial setting period (about 20 minutes) by covering the restoration surface with a varnish or unfilled resin.
6) After the initial set, the restoration surface is contoured with a diamond finishing bur on a high-speed water-cooled handpiece, and then finished with finishing stones and discs on a low-speed hand piece.
7) Due to the prolonged curing time of GIs (months), the restoration surface and marginal tissues are sealed by re-etching and applying a bonding agent. This technique is referred to as “rebonding.”

Resin Composites

Dental composites are the most commonly used restorative materials in veterinary dentistry. A composite is a solid material formed from multiphased materials that have been combined to produce properties superior to the individual constituents. They are easy to apply, provide acceptable strength and wear resistance, and are aesthetically pleasing. Modern composite
bonding systems to dentin and enamel require limited cavity preparation and greatly reduce marginal leakage. Bonding to cementum has not been investigated.

All commercial dental composites use free radical initiators to start an addition polymerization reaction. These free radicals are activated either chemically, or by an external energy source (e.g. a curing light), or by a combination of the two mechanisms.

*Light Activated Resins* (*light-cured*) are packaged as a single paste in a light-proof container (e.g. syringe or compule). The advantages of light activated resins are an unlimited working time for material placement and a short, “on demand” set time (usually 30 to 60 seconds). While some new materials are available with curing depths up to 4 mm, the curing depth for light activated resins is accepted to be approximately 2 mm. Therefore, deep restorations must be applied using a layering technique (incremental buildup). The curing light should be held within 1 mm of the restoration to optimize light exposure; however, light activated resins are also initiated by visible light and must be protected from sunlight, surgical lamps, and room lights during application.

*Chemically Activated Resins* (*self-cured, auto-cured*) are packaged as two paste systems. Upon mixing, polymerization begins, and the composite sets into a solid within 3 to 5 minutes. Heat will increase both the rate and degree of polymerization. Chemically activated resins are usually used for large bulk fill restorations or restoration with limited light access.

*Dual-Cure Resins* are chemically activated resins in which a light activation system has been added to each paste and are indicated in restorations where light cannot penetrate the entire depth of the restoration. Light activation attains the initial set of the restoration, and the chemical activator completes the polymerization.

Whether the composite is light or chemically activated, the polymerization reaction continues for at least 24 hours before the resin is completely cured. An unfilled resin coating (dentin bonding agent) should be applied to protect the restoration from air and oral fluids during this curing period (*Rebonding Technique*).

Historically, the most significant problem with dental composites has been shrinkage of the material during polymerization. This shrinkage creates a gap between the restoration and the cavity wall which creates an imperfect seal allowing for oral contamination and bacterial penetration and is referred to as *marginal leakage*. In order to reduce this volumetric change, high levels of filler particles are added to the composite material. Increased filler loading increases the restoration hardness, fracture strength, and wear resistance and reduces thermal expansion and contraction. While filler loading minimizes marginal leakage and improves the mechanical properties of the restoration, it also results in a viscous material with poor handling characteristics.

Numerous composite materials are manufactured in an attempt to maximize the physical, mechanical, and handling properties required for different restorative applications.

Dental composites are commonly classified by the filler particle size. Those most relevant to equine dentistry are listed:
Hybrid Composites: These composites have a high filler content, and contain various sizes of particles ranging from 0.04 to 4um. They are currently the preferred restoration material in human and veterinary dentistry because of their wide range of uses, their superior clinical properties, wear resistance, and acceptable polishability. They are used in both stress bearing and aesthetic restorations.

Microhybrid Composites were developed to offer a composite for both high stress as well as aesthetic restorations. This is the most popular category of composites because of its versatility.

Flowable Composites: This subcategory of hybrid composites consists of low viscosity (syringeable) composites with reduced filler content which flow and adapt intimately to the cavity walls, and the use of flowable composites as a “filled-adhesive” is an accepted practice in human dentistry. In this application, a flowable composite layer is placed between the bonding agent and a stiffer structural composite to ensure thorough wetting of the adhesive and act as a stress absorbing layer. Negatively, the reduced filler content produces a composite that lack strength and wear resistance; therefore; flowable composites are only recommended in low stress restorations and restorations with poor accessibility. The restoration of equine teeth with flowable composites has become a common practice because of the material’s handling characteristics; however, this application must be questioned due to the poor mechanical properties of the material.

Nanofilled Composites: The nano-particle size (0.005-0.01um) allows for increased filler loading which improves strength and wear resistance, minimizes shrinkage, and provides superior polishability. Nanocomposites have rapidly gained popularity in both human and veterinary dentistry because of their clinical properties and aesthetics. Recent clinical trials comparing the clinical performance of nanofilled, microhybrid, hybrid, and packable resin composite restorations in load bearing applications on human molars have shown no statistically significant difference between the composite materials.

Core (Buildup) Composites are high strength composites designed for placement under prosthodontic crown restorations where significant tooth structure has been lost. Filler particle sizes vary from micro to macro, and polishability is poor. Anecdotal success in equine restorations of incisor fractures and extensive decay has been reported.

Dentin-Enamel Adhesives (Bonding Agents)

Resin composite materials will not bond to dental tissues; therefore, composite restorations require an adhesive application between the tooth and the restoration to which the composite can copolymerize. The adhesive used in dental applications is a dentin bonding agent. The two most commonly used bonding systems are “Etch and Rinse” (5th generation) and “No Rinse” (6th Generation) systems.

The “Etch and Rinse” (ER) category is divided into two or three step systems in which the first step is always the etching (conditioning) the tooth surface (Step 1). In the Two Step ER system (One Bottle System) a primer and adhesive resin overlayer are applied in a single application
(Step 2). In the Three Step ER system, the primer and adhesive resin overlayer are applied separately (Steps 2 and 3). Within the “Etch and Rinse” category of bonding agents, the Two Step (One Bottle) system is the most popular. While both the Two and Three Step ER systems produce acceptable bonding strengths to both enamel and dentin, the 3 Step ER system has superior bonding to dentin.

The “No Rinse” (NR) (self-etch, self-priming) category is divided into one or two step systems. In the One Step NR system the conditioner, primer, and adhesive resin overlayer are all applied together from a single bottle. In the Two Step NR system the combined conditioner and primer components (first bottle) are applied followed by the application of the adhesive resin overlayer (second bottle). The “No Rinse” bonding systems have failed to produce clinically acceptable bonding strength when compared to the “Etch and Rinse” systems.

The Acid-Etch Technique

35% phosphoric acid is the “gold standard” etchant, although other acids (e.g. polyacrylic acid) and varying acid concentrations are available. Etchants are available in liquid and gel forms, with the gel being the most popular because it is easier to dispense and because it retains its placement during vertical applications.

The etching procedure includes the following steps:

1. The preparation is isolated to prevent contamination from blood or oral fluids.
2. The tooth and cavity preparation are cleaned with non-fluoride, flour pumice to remove the organic pellicle, plaque, food, and other oral fluids. The pumice is mixed with water into a thick paste and applied with a prophy cup on a low-speed handpiece. Fluoride polishing paste is contraindicated because it interferes with the etching reaction.
3. The cleaned area is rinsed and gently air dried.
4. The etchant is applied to the preparation for appropriate contact time, and then thoroughly rinsed off with water. The standard contact time for dentin is 10-15 seconds and for enamel is 30-40 seconds. The etching time for coronal cementum has not been established; however, the author allows 20-30 seconds contact time for cementum. Over etching should be avoided since a contact time over 120 seconds leaves insoluble calcium precipitates on the surface of enamel.
5. The etched surface is dried according to the adhesive material instructions. Most enamel bonding systems require a dry etch surface, and properly conditioned enamel has a chalky-white or frosty appearance. If this appearance is not achieved, the surface should be re-etched. Most dentin bonding systems require a moist surface with a glistening appearance. Drying the dentin desiccates and collapses the collagen fibrils, which prevents proper bonding.
6. The conditioned tooth is protected from contamination until the restoration material is applied. In the sedated horse this often necessitates that an assistant cover the prepared tooth with sterile gauze while the operator prepares the restorative material.

The Basic Technique for a Composite Restoration

1. The cavity or endodontic access is prepared (Cavity Preparation).
2. In deep cavity preparations and endodontic access restorations a liner and/or base material (e.g. Calcium Hydroxide, Glass Ionomer, or Reinforced Zinc Oxide-Eugenol Cement) may be applied.

3. The walls of the cavity are conditioned (Acid Etch Technique).

4. A bonding agent is applied to all etched surfaces with a disposable brush and light cured. Most manufacturers suggest two applications of the bonding agent.

5. The resin composite is applied into the cavity and shaped with a plastic instrument. Chemical cure composites are typically applied in bulk, while light-curing and dual-curing composites are applied and cured in 2 mm increments to allow for proper curing of composite and to minimize the shrinkage of the restoration. (Incremental Buildup).

6. The cavity is filled to the coronal margin, or slightly overfilled.

7. The restoration surface is contoured with a diamond finishing bur on a high-speed water-cooled handpiece, and then finished with finishing stones and discs on a low-speed hand piece.

8. The restoration surface and marginal tissues are sealed by re-etching and applying two coats of bonding agent. (Rebonding)

Case Follow-Up

Long-term clinical trials to determine the performance of restorations in equine teeth are lacking, and treatment success must be determined on each patient through follow-up examinations. The author recommends evaluating the restoration at 3, 6, and 12 months postoperatively. Annual radiographic evaluation is recommended.

Summary

While restorative dentistry in equine patients was practiced during the last decade of the 19th century, this dental discipline received minimal attention until the first decade of the 21st century. The resurgence of veterinary dental care in the 1990s stimulated practitioners to investigate the tooth preserving dental disciplines (endodontics, orthodontic, periodontics, and restorative dentistry). Accepted dental procedures and material applications have been extrapolated from human and small animal veterinary dentistry for use in the equine patient and anecdotal reports of success support the continuation of these practices. However, treatment failures and the inappropriate selection and application of dental materials demonstrates the need for scientific investigation and formal training in advanced dental procedures instead of the current widespread state of experimentation on equine patients. With continued case reporting by practitioners and clinical research by universities, our restorative treatment decisions in equine patients will become evidence-based.

References Available Upon Request
Endodontic Treatment of Equine Incisors

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Introduction

Traumatic injury to the incisors is relatively common in the horse. A complicated crown fracture (CCF) by definition results in pulp exposure (PE). Exposure of the pulp to the oral environment results in bacterial infection of the coronal aspect of the pulp, and in brachydont species, inevitably leads to pulp necrosis. Clinical management in the brachydont species is vital pulpotomy (VP) with direct pulp capping (if the PE is iatrogenic or acute), root canal therapy, or extraction. The pulp of the hypsodont tooth appears to be much more “dynamic,” and CCF does not always result in irreversible pulpitis and pulp necrosis in incisors or cheek teeth. Therefore, the clinical management of the equine PE varies from the standard recommendations in brachydont species. Root canal therapy in the immature permanent incisor versus the permanent incisor with a closed apex will be discussed.

Materials and Methods

Radiography

Radiographic evaluation of the equine dentition has been described.¹ The equine incisors are best evaluated using intraoral placement of the film, phosphor plate or direct digital sensor. A bisecting angle technique is used to reduce elongation and foreshortening artifacts. Multiple views at oblique angles are important in the detection of reserve crown/root fractures and evaluation of the root canal anatomy. Proper technique is important in identifying subtle pathology and recognition of artifact.

Computed tomography (CT) has been an important imaging tool in the study of the endodontic anatomy of the equine incisors and cheek teeth. This complex endodontic anatomy is not appreciated with standard radiographic techniques, and the limitations should be kept in mind when evaluating the radiographic image of the equine incisor before and after endodontic treatment.

Vital Pulpotomy and Direct Pulp Capping

Iatrogenic pulp exposure during crown reduction of incisor teeth is an indication for immediate vital pulpotomy and direct pulp capping. The objective is to remove the coronal portion of the pulp and to place a medicament on the pulp that will be both antibacterial and conducive to the production of a dentinal bridge by odontoblast cells. The procedure for vital pulp therapy is described in detail in these proceedings.
Traditional Root Canal Therapy

In cross section the shape of the incisor root canal is flattened centrally adjacent to the infundibulum. A small endodontic file may be needed to document PE mesial or distal to the infundibulum. Apical to the infundibulum the cross-sectional dimensions of the canal become round to oval, flattening in the mesio-distal dimension to an hour-glass shape or dividing into lingual and labial branches that may rejoin before ending at the apex. In the immature permanent tooth the apex is large and open. With elongation of the root, the apex moves to a lateral position, and its dimensions become quite small.

Root canal therapy consists of:

- Instrumentation of the canal to facilitate removal of all pulpal tissue and sterilization of the canal
- Obturation of the canal (hermetic seal)
- Placement of a restoration that is impermeable to bacterial penetration

Techniques of shaping the canal for effective removal of all pulpal tissue and disinfection are continually being improved in human and small animal dentistry, and a wide array of materials are available. The goal in brachydont teeth is to instrument the canal to a conical shape. This geometry allows for efficient irrigation with disinfectant solutions, typically diluted or full strength bleach. Bleach is not only antimicrobial, it also very effectively dissolves soft tissue. This process is generally initiated with small hand files that are used to gauge the canal’s anatomy and establish the working length to the apex. The process is continued with either hand or motorized rotary files in a step-wise fashion until all pulp tissue is removed and clean white dentinal shavings are created with the file. While hand files are commercially available at lengths appropriate for the equine incisor, it is not possible to instrument a continuously tapering canal in the equine incisor due to the length and anatomy of the canal. Effective cleaning and sterilization of the apical canal in the horse is therefore always in doubt.

Access to the root canal of the permanent incisor may be through the occlusal plane (often the fracture plane) or labially, on the facial aspect of the clinical crown. The latter access provides straight line approach to the apical aspect of the root canal, and largely eliminates the interference of the apical infolding of the infundibular enamel. However, this approach, which involves removal of an area of enamel and dentin on the labial aspect of the crown, may predispose the tooth to further fracture. Typically the access is created initially with a small carbide bur (#2 round) in a high speed handpiece with water irrigation. This is enlarged with a larger (#8 round) bur and coarse diamond burs. A Gates Glidden drill on a low speed handpiece is then used to enlarge the pulp chamber by removing dentin from the lateral walls. Gates Glidden drills will not efficiently cut the enamel of the infundibulum. Surgical length carbide burs on a high speed handpiece are necessary for removal of infundibular enamel at the access. In young incisors, it may be necessary to use laminectomy burs (on a Hall air drill) to obtain sufficient length to remove adequate infundibular enamel.

Once access has been created, removal of the pulp is initially performed with barbed broaches, which can be purchased in 45 mm lengths. In some cases, the pulp can be removed nearly intact, but more often the necrotic pulp is difficult to remove with the barbed broaches, and chemical
dissolution with 5% hypochlorite (Chlorox bleach) is necessary. Since bleach is highly irritating to tissues, efforts should be made to protect the adjacent gingiva and oral mucosa and skin. This can be accomplished with latex rubber dental dams, latex exam gloves, and/or frequent irrigation with water. Contamination of the access by saliva can usually be managed by the above measures in addition to packing off the tongue and oral cavity with a surgical towel or lap sponges.

In addition to constant irrigation with full strength bleach, an EDTA-urea peroxide lubricant gel is useful in the initial instrumentation, as this promotes breakdown of the organic material, aids in lubrication and the peroxide helps “bubble up” the organic debris from the canal. An intraoperative radiograph is obtained to confirm that a small file is at the apex of the canal; this determines the working length. Subsequently, larger files are sequentially used, with continuous replenishment of full strength bleach, until the canal diameter is enlarged at the apex. Larger files are used in a “step-back” technique to shape the canal in a continuous tapering fashion. When the canal has been instrumented to the point of getting clean dentinal shavings, a final bleach rinse is followed by drying with sterile paper points. A gutta percha master point of the same size as the largest file used at the working length is inserted, checked for “tug back,” and a radiograph obtained to ascertain adequate apical fill. A spreader is then chosen that can be inserted to within 4 mm of the working length.

Obturation of the canal typically consists of coating the cleaned canal with a root canal sealer cement followed by packing the canal with gutta percha. Zinc oxide-eugenol (ZOE) is the traditional sealer cement. It can be spatulated to the desired consistency and delivered to the apical aspect of the canal with a small gauge spinal needle on a custom luer lock syringe, or with a 60 mm spiral filler on a low speed handpiece. A K-file that reaches the working length can also be used in a clockwise fashion to fill the apical region and coat the canal walls with sealer cement. The pre-selected master cone is then placed and another radiograph obtained to confirm good apical obturation. The packing process is accomplished by lateral “condensation” with cold or heated spreaders, followed by introduction of additional, accessory gutta percha points. Flat ended pluggers are used to vertically compact the gutta percha. Here again, although gutta percha points, spreaders and pluggers of an appropriate length can be purchased or fabricated, the complex canal anatomy usually precludes obtaining a complete fill, even with abundant sealer cement, and voids are often evident on postoperative radiographs. Indeed, complete obturation of the canal is extremely unlikely, even in the absence of radiographic voids.

Finally, and of most importance, the access to the root canal is repaired in a manner that will prevent any leakage of oral fluids (bacteria) into the canal. Amalgam has by-in-large been replaced with glass ionomer, resin composite or a mixture of these materials, which are bonded to the tooth. Unlike the brachydont tooth, the equine hypsodont incisor undergoes continuous wear of the occlusal aspect of the crown, elongation of the root and eruption of the tooth. The amount of wear and eruption per year is age dependent, but must be taken into account when performing equine root canal therapy. Otherwise, the restorative material will be worn away with time, permitting contamination of the obturated canal. Therefore, the gutta percha is limited to the apical ¾ of the root canal, leaving about 10-15 mm of the coronal canal to fill with a glass ionomer and/or composite restorative.
Root canal therapy of the immature permanent incisor with an open apex requires additional steps prior to obturation. The two standard endodontic techniques for treatment of the immature permanent tooth are apexigenesis and apexification. In the first instance, the tooth is treated much like a vital pulpotomy, allowing for the continued development of the tooth with eventual apical closure. If the tooth remains vital, then no further treatment is needed. If, however, the pulp is or becomes necrotic, then apexification techniques are used to create an apical stop for traditional root canal therapy. In the traditional apexification procedure the entire pulp is removed and the canal is filled with calcium hydroxide. This sterilizes the canal and stimulates calcification and closure of the apex, at which time root canal therapy can be performed. More recently, mineral trioxide aggregate (a derivative of Portland cement) has been used to create an apical stop so that a one step apexification and root canal therapy can be used for endodontic treatment of the immature permanent tooth. This technique has not yet been reported in the horse. Most recently in human dentistry, there has been successful stimulation of mesenchymal stem cells that are present in the apical region of the immature permanent tooth, with regeneration of pulp after removal of the necrotic pulp from the nonvital tooth. Regenerative endodontic techniques have not been reported in the horse.

Discussion

The conditions seen clinically in equine practice that require consideration of endodontic therapy of incisor teeth are below:

- Acute iatrogenic PE during occlusal adjustment (crown reduction)
- Acute or peracute complicated crown fracture of
  - Immature permanent incisors
  - Mature permanent incisors
- Long-standing PE of mature permanent incisors (from prior fracture or iatrogenic PE)

In the author’s experience, a high percentage of equine permanent incisors with longstanding pulp exposures have radiographic evidence of having formed a dentinal bridge and continued root development, indicating tooth vitality. It should be noted that this appears to be a unique feature of the equine hypsodont incisor. While there may be an occlusal defect and a significant pulp chamber/root canal cavity, more often than not there is no radiographic evidence of periapical bone lysis associated with periapical pathology, and no fistulation evident on oral examination. In these situations, it does not appear to be necessary to remove the dentinal bridge and instrument the root canal to the apex. Rather, the coronal pulp chamber/root canal can be debrided coronally with carbide and diamond burs on a high speed handpiece, and more apically to the dentinal bridge with hand files, in a similar fashion as performing the standard root canal therapy. However, no obturation is performed, and a restorative material is used to fill the defect, as described for access restoration above. Care must be taken to light cure composite restorative materials in 2-4 mm layers (following the manufacturer’s instructions) to avoid restoration failure associated with shrinkage that occurs during polymerization of the composite material. As light exposure of the restorative material at the depths of a long and narrow cavity may not be adequate to initiate polymerization, use of a rapid hardening calcium hydroxide cement or a self-curing glass ionomer are better choices for the apical portion of the restoration. After this material has set, the walls of the defect can be cleaned with an endondontic spoon excavator,
acid etched, rinsed with water, air dried and restored with a dentin bonding agent and a microhybrid composite in incremental layers.

References and Footnotes

1. Baratt RM. Equine Dental Radiography (this proceedings).
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   a. RC Prep, Medical Products Laboratories, Philadelphia, PA.
   b. DyCal, Dentsply, York, PA.
Applied Bitting to Dental Disease

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Primum non nocere (First, do no harm), Hippocrates (circa 460-377 BCE)

Horses have been subdued with bit and bridle for over 5000 years. Man first fashioned bits from plaited vines, wood, antler, and bone. Bronze bits were introduced about 3000 years ago, followed by copper, iron, and steel. More recently, bits have been fashioned from stainless steel, plastic and other synthetic materials. Modern bits and bridles place pressure on at least 8 areas (mouth, bars, lips, cheeks, tongue, hard palate, chin groove, nose, and poll) of the horse’s head. ¹

Oral ulcerations and injuries caused from the bit were recognized and recorded in early veterinary literature.²,³ These were first thought to be caused from the bit pulling the oral soft tissues against sharp enamel points on the cheek teeth. Sharp teeth have been blamed for “bad behavior”, “lugging out” or “off leg lameness”, and have been associated with oral ulceration and cheek pain. Sharp points on the lower cheek teeth have been associated with bit injuries to the tongue.³ The remedy recommended to alleviate these problems was “the rasp”. Mayhew described injuries caused from the harsh use of the bit in the lip commissures, cheeks, tongue, bars of the mouth, and chin groove. He recognized early on that all these injuries were not attributable to sharp tooth points.⁴

In the early 20th century, “dressing of teeth” became more of a common procedure. Sharp enamel points were thought to attain the greatest size in the 5-8 year-old and they could wound the cheeks of drivers, reiners, and saddle horses. On this subject, Merillat gave the following comment:

“The aim in dressing the teeth of a horse should be to simply blunt the enamel points along the course of the arcades and to ‘round up’ the first superior and first inferior molars as smooth as an ivory ball to allow for the seat of the bit”.

A few carefully directed strokes of the float equipped with the rasp blade will rapidly blunt the sharp projections to the desired point. Rounding the borders of the molars was unnecessary and harmful. He went on to state that sharp enamel points would begin to recur in about three months but not of sufficient degree to produce injury until 12-18 months.⁵

In the mid 20th century, equine veterinarians and tooth floaters described bit seating as the rounding of the first cheek teeth to reduce enamel points and contouring the teeth to decrease cheek pressure and injuries from the bite.⁶⁻⁹ Scoggins¹⁰ wrote that rounding off buccal/occlusal surfaces of the maxillary teeth and lingual/occlusal surfaces of the mandibular cheek teeth and anterior/occlusal surfaces of all four 1st cheek teeth will help reduce discomfort induced by bits

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and bridles. Additionally, smoothing and shaping the last molars posteriorly allows a more comfortable relaxed lower jaw. The more aggressive the demands of the sport (polo vs. pleasure riding), the more justified is an aggressive approach to shaping cheek teeth. He described the use of hand tools and power dental grinders to perform these procedures. The danger of thermal damage to the pulp and direct pulp exposure was cautioned.\textsuperscript{10}

The role of wolf teeth in causing oral pain has been controversial. The fact that these vestigial teeth do not serve a purpose and may possibly cause discomfort and training issues has resulted in the common practice of extracting wolf teeth. Sharp wolf teeth may cause buccal ulcerations and pain when the noseband or bit forces the soft tissues into these teeth. Wolf teeth in the young horse are often slightly mobile and bit contact may cause pain as the horse is ridden. Loose or diseased wolf teeth may also cause oral pain and contribute to training problems. Lower wolf teeth and ‘blind’ wolf teeth or wolf teeth positioned rostrally in the interdental space frequently are contacted by the bit and cause pain and major training problems. Due to the close proximity of the wolf tooth to the 2\textsuperscript{nd} premolar it can be impossible to round the rostral edge of the first cheek teeth. Some veterinarians float or grind the wolf tooth as they round the 2\textsuperscript{nd} premolars. This may result in the wolf tooth becoming loose or exposure of the sensitive pulp of the wolf tooth causing pulpitis and possible infection. Both problems cause pain for the horse and should be avoided.

Two studies have shown a high incidence of oral ulcers in bitted horses as compared to horses not ridden in bit and bridle.\textsuperscript{11,12} A more recent study supported the time-held beliefs that the standard practice of floating teeth to reduce sharp buccal and lingual points (without bit seating), is not effective in preventing oral ulcerations in ridden horses.\textsuperscript{12}

A clinical study on 20 horses showed an improved trainer perception of athletic performance and responsiveness to the bit after dental floating and bit seating.\textsuperscript{13} A later study showed no positive effect on dressage scores in performance horses post routine floating.\textsuperscript{14}

Controversy still exists as to the degree to which the crown of the 2\textsuperscript{nd} premolar should be reduced. Complications from excessive bit seats include damage to the rostral pulp horns of the 2\textsuperscript{nd} premolar.\textsuperscript{15,16} Course tungsten carbide blades have been shown via electron microscopy, to severely damage dental crown structures and expose dentine tubules. Power tools have the potential to damage dentine tubules and odontoblastic processes or expose the pulp from over-reducing the crown.\textsuperscript{16,17} Motorized burrs generate heat and thermal damage to pulps is possible even though direct exposure does not occur.\textsuperscript{17}

Bettiol and Dixon\textsuperscript{16} showed that you can indirectly assess the thickness of secondary dentine over the 6\textsuperscript{th} pulp horn from the mesial edge of the 1\textsuperscript{st} cheek tooth (06s). The greater this distance, the thicker the occlusal layer of secondary dentine and the lower the risk of pulp exposure of the 6\textsuperscript{th} pulp horn. The converse is also true. Aged horses were found to have less occlusal secondary dentine and to be at an increased risk of pulp exposure.\textsuperscript{16}

The incidence of buccal ulcers can be quite high in horses ridden with bit and bridle. Removing sharp enamel points (Floating) on bitted horses without contouring the front teeth will not prevent oral ulcerations opposite the upper 06s and in the lip commissures. Further studies need
to be performed to determine the effects of rostral contouring (bit seating) on the incidence of oral ulcerations in the bitted horse.

Such findings and clinical evidence has lead some to feel strongly that the bit is inhumane; and it certainly is, in untrained hands. Merillat (1915) mentioned bit gnathitis and recommended better mouthing or bitting practiced by the trainer rather than more dentistry. He agreed with recent recommendations by Tell\textsuperscript{12} that alternating days in training with a broken snaffle and straight bit and using a lighter hand will remedy most problems.\textsuperscript{4,12} Training in a bitless bridle or hackamore is another practice recommended to reduce or alleviate bitting injuries.\textsuperscript{12,18}

If our true mission as veterinarians is to help prevent disease and protect the welfare of the horse, we should address the issues of bitting and oral health with in-depth studies and research. We need to clearly show the proper method for safely and proficiently “dressing the bitted horse’s teeth”. Our primary goal is, \textit{First, do no harm.}

**References**

2. Youtt W. The Horse: with a treatise on draught. 1\textsuperscript{st} ed, Paternoster Row, London:Baldwin and Cradock 1831;146-147.
3. Dadd GH. The modern horse doctor. 12\textsuperscript{th} ed, New York Saxton, Barker, and Co 1860;231-232.
