

The Gross, Histological, and Ultrastructural Anatomy of Equine Teeth and Their Relationship to Disease

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1. Evolution of Equine Teeth

The precursor of the modern horse *Equus caballus* was a small, rabbit-sized animal named *Hyracotherium* (also known as "Dawn Horse" or Eohippus) that lived in America about 70 million years ago. This animal lived on succulent plants that caused little dental wear on its short crowned (brachyodont) teeth, which were similar to human or canine teeth. However, subsequent major climatic changes resulted in *Hyracotherium's* habitat becoming covered with coarse grassland. Some of *Hyracotherium's* descendants evolved to survive on this coarse grass diet by developing cecal and colonic digestion to use cellulose-containing foodstuffs. However, the ingestion of large quantities of coarse foodstuffs that contained much abrasive silicate (which is harder than enamel) for prolonged periods (up to 20 h/day on poor-quality diets) placed great demands on the teeth of these primitive horses. A compensatory, parallel evolutionary change was the development of hypsodont (long crowned) teeth, with the long reserve crowns embedded in the deepened alveoli of the premaxilla (incisive bone), maxilla, and mandible.¹

In brachyodont species (e.g., humans, dogs) the permanent teeth fully erupt before maturity and are normally long and hard enough to withstand normal attritive (wear) forces and so survive for the life of the individual. In contrast, equine hypsodont teeth slowly erupt (do *not* grow) over most of the horse's life at a rate of about 2–3 mm/yr. This eruption rate is similar to the rate of attrition of the occlusal surface of the tooth, provided that the horse is fed on grass (or some alternative fibrous diet, e.g., hay or silage), rather than being fed high levels of concentrate food. The horse's ancestors also enhanced the efficiency of their chewing by evolving complex premolars that resemble molars. Consequently, equine premolars and molars can collectively be termed "cheek teeth." *Hyracotherium* had four premolars and three molars in each jaw. The first premolar (wolf tooth) later became much smaller, and in the modern horse, is non-functional if present.

Further adaptations to grazing in horses are the presence of limited rostral-caudal jaw movement and restricted opening of the temporomandibular joint (which makes clinical examination of equine cheek teeth very difficult). The development of six pow-

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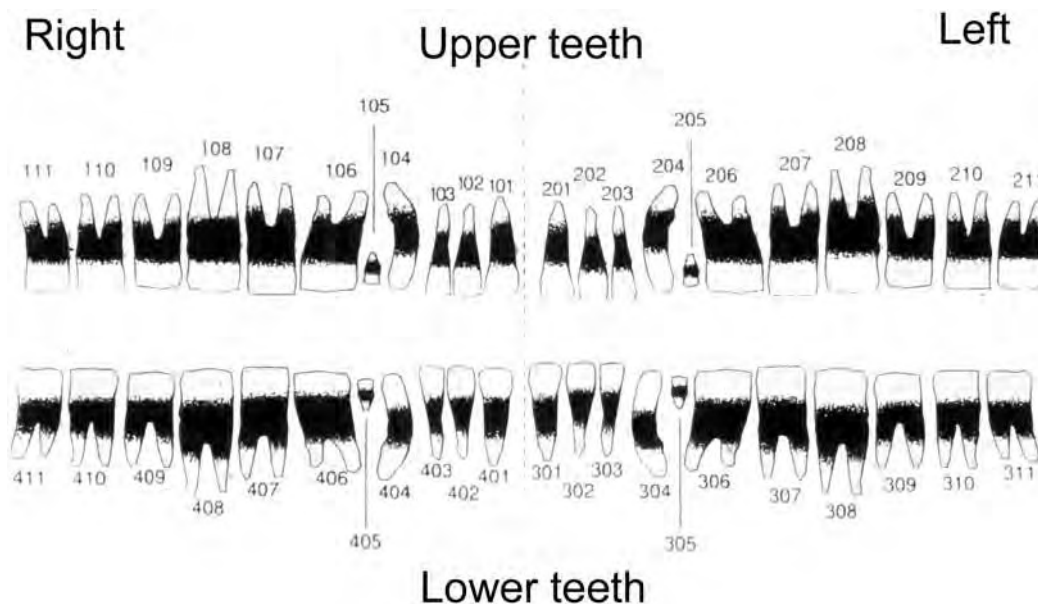


Fig. 1. The Triadan system of dental nomenclature.

erful mandibular muscles (including the masseter, temporalis, and the two pterygoid muscles) enables the necessary prolonged and forceful closure and side-to-side grinding movements of the jaws.

2. Equine Dental Classification

The Triadan method for identifying individual teeth (Fig. 1) is increasingly used in equine dentistry and has many advantages. As illustrated for adult teeth, the quadrants are numbered from 1 to 4 in a clockwise direction, beginning at the right maxillary quadrant. However for deciduous teeth, these same quadrants are numbered from 5 to 8. For example, the first right maxillary deciduous cheek tooth (Triadan 508) is replaced at about 2.5 yr of age by its permanent successor, Triadan 108.

Adult mammals have four types of teeth: incisors, canines, premolars, and molars (in rostro-caudal order). Teeth embedded in the premaxillary bone are by definition termed incisors, as are those embedded in the rostral mandible. In male horses, the most rostral tooth in the maxillary bone is the canine tooth ("tush"). The horse's dentition is classified as diphyodont, i.e., they have two sets of teeth, termed temporary (deciduous, primary, or milk), which only include the incisors and the premolars, and permanent (secondary or adult) teeth. The deciduous first through third cheek teeth (i.e., Triadan 06s–08s; second through fourth premolars) of the young horse are replaced by three permanent premolars in the adult. The canine (104), first premolar (105), and three molars (09s–11s; fourth through sixth cheek teeth) have no deciduous precursors.

3. Equine Dental Nomenclature

The occlusal or masticatory surface is the area of tooth in contact with the opposing teeth. The term

crown refers to the enamel-containing part of the tooth, and in brachyodont teeth, refers to the enamel covered, erupted aspect of the tooth. However, in young horses, most of the dental crown is unerupted or reserve crown. The short portion of the crown visible in the equine oral cavity is termed the clinical or erupted crown. Coronal is used as a term relating toward the occlusal surface. Apex (apical region) refers to the area of tooth furthest away from the occlusal surface, i.e., the area where the roots develop, and the term apical also refers to the direction opposite to coronal. Lingual refers to the medial aspect (area closest to the tongue) of the lower teeth, while palatal refers to the same (medial) aspect of the upper teeth. Buccal refers to the lateral aspect (aspect closest to cheeks) of both upper and lower (cheek) teeth, while labial refers to the rostral and rostro-lateral aspect of teeth close to the lips (incisors only in horses). The terms interdental (interproximal or proximal) refer to the aspects of teeth that face the adjoining teeth in the same row.

The terms mesial (in a direction toward 01s) and distal (in a direction toward 11s) is used to refer to the position of teeth in species that have a true dental arch. However, it is an inappropriate term for use on the cheek teeth of horses that have a large interdental space (i.e., between the incisors and cheek teeth, "bars of the mouth") and whose cheek teeth are in straight rows rather than an arch. Therefore, the term rostral and caudal is more appropriate to relate to the position of the cheek teeth in the cheek teeth rows. However, the terms mesial and distal could be used with equine incisors, which do form a true arch.

By definition, the term tooth root specifically refers to the apical area that contains no enamel. At eruption, hypsodont teeth have no true roots—

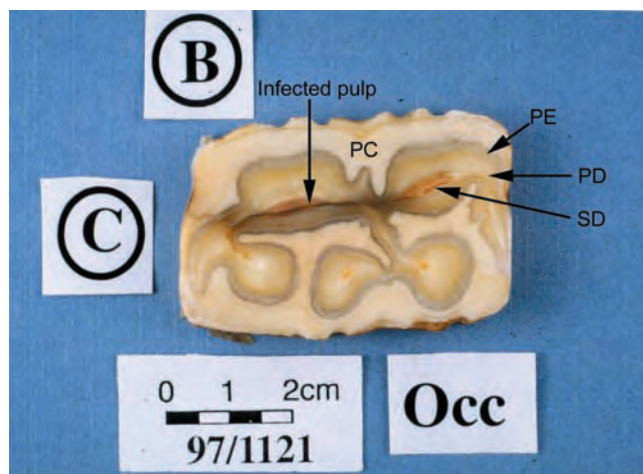


Fig. 2. Transverse section of a mandibular cheek tooth. Note the very exaggerated infolding of peripheral enamel (PE) in this mandibular cheek tooth compared with the more limited infolding present in maxillary cheek teeth (Fig. 3). The large amount of peripheral cement (PC) greatly contributes to the substance of this tooth. The pale primary dentine (PD) can be recognized, as can the thin layer of brown, secondary dentine (SD). B = Buccal aspect. C = Caudal aspect. In this particular tooth, two pulp cavities are infected. Figure courtesy of Mr. Ian Dacre.

these begin to develop about a year or so later. The term apical is a much more appropriate term for this area of hypsodont teeth, that for example, commonly develop apical infections of the mandibular second (107,207) and third (108,208) cheek teeth even before the development of any roots. The term “tooth root abscess” is inappropriate in such cases.

4. Occlusal Surface of Equine Teeth

The continuous wear on the surface of hypsodont teeth leads to the presence of alternate layers of the three calcified dental tissues (enamel, dentine, and cementum) on the occlusal surface. This is in contrast to the sole presence of enamel on the occlusal surface of human teeth. The presence of infolding of the peripheral enamel (most marked in the lower cheek teeth) (Fig. 2), and also of the two blind enamel cups (infundibula) in the upper cheek teeth (Fig. 3) (there is also a single infundibula in all incisors) increases both the length and irregularity of the exposed enamel ridges on the occlusal surface. The different calcified tissues wear at different rates (enamel slowest, dentine intermediate, and cementum fastest), and therefore, a permanently irregular occlusal surface is created by a self-sharpening mechanism that is advantageous for the grinding of coarse, fibrous foodstuffs. In addition to the above irregularity, the cheek teeth also have a series of transverse ridges on their occlusal surfaces that will be discussed later.

Because the softer dentine and cement on the occlusal surface wears more quickly than the sur-

rounding enamel, the dentinal and cemental surfaces become depressed. The depth of these depressions is related to the surface area of the dentine and cementum, with larger exposed areas more deeply recessed.² In contrast, smaller exposed areas, being better protected by the surrounding enamel, have less wear. Therefore, the orientation and invaginations of the enamel folds (including infundibula) play an important role in dividing the occlusal surface of dentine and cementum into smaller areas and thus protecting it from excessive attrition.²

The wear process on the occlusal surface of equine teeth is a complex phenomenon, depending on the type of diet, individual and breed variation in the hardness of dental tissues, the ingestion of hard phytoliths (grit) in the diet, the force and the direction of the chewing action, the sizes, shapes, and angles of the opposing occlusal surfaces, and the relationship of cusps and crest patterns to the occlusal motion of cheek teeth. The occlusal surface is covered with an organic covering termed a pellicle, which seems to seal the openings of odontoblast processes (of dentine producing cells whose bodies lie in the pulp periphery—described later). Some odontoblast processes can be seen beneath the pellicle in normal equine teeth, but there must be some seal in these dentinal tubules over the pulp (e.g., a “smear layer” of ground teeth) to prevent the ingress of oral microorganisms into the pulp.²

In teeth with developmentally limited infolding of peripheral enamel (Fig. 4), developmental absence of infundibula (Fig. 5), or in older teeth where the infundibulum is worn out (Fig. 6), excessive wear

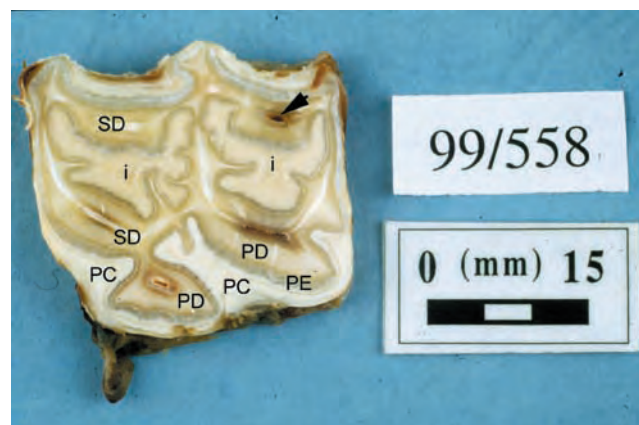


Fig. 3. Transverse section of a maxillary cheek tooth. Note the large amount of peripheral cement (PC) in this tooth, which highly contributes to its structure. In this particular tooth, both infundibula (i) are completely filled with cementum with no evidence of a vascular channel (or caries) running through it. Pale primary dentine (PD) can be identified, as can the thin layer of secondary dentine (SD) elsewhere on the tooth. There are pathological changes to the pulp cavity and adjacent secondary dentine in three of the five pulp cavities, evidenced by discoloration (arrowhead). Figure courtesy of Mr. Ian Dacre.

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Fig. 4. Occlusal surface of mandibular cheek teeth with limited enamel infolding. The occlusal surface of the middle mandibular cheek tooth shows a developmental limited infolding of the peripheral enamel (arrows) with subsequent excessive attrition of dentine, leading to deep depressions in the central primary and secondary dentinal areas. This tooth would be less effective at grinding food than a normal tooth.

will occur in the smooth enamel-free dentinal and cemental areas that are termed “smooth mouth.” Depressions termed senile excavation (“cupping”) of these areas can then occur, with sharp edges developing on *both* sides of the teeth, including the buccal aspect of lower cheek teeth and the palatal aspect of the upper cheek teeth. Severe “cupping out” may even predispose to dental fractures. With advanced age, some teeth will be composed almost

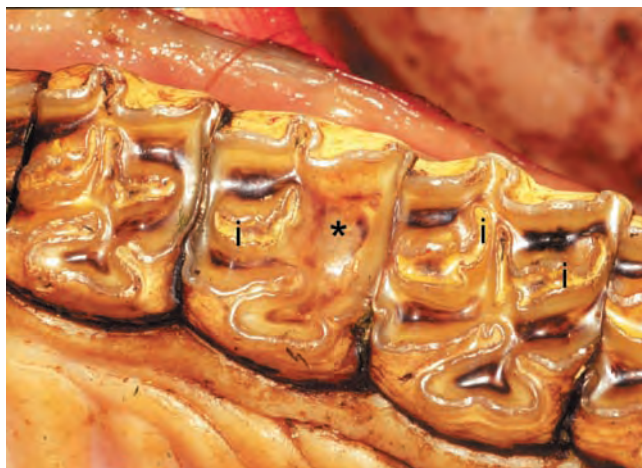


Fig. 5. Occlusal surface of a maxillary cheek tooth (2nd from left) with just one infundibulum. The occlusal surface of this maxillary cheek tooth has just a single infundibulum (i), indicating developmental absence of this structure, or alternatively, that it was an extremely shallow infundibulum that became worn away within 1 yr or so of dental eruption. Note the excessive wear (depression) in the dentine at the site (star) of the missing infundibulum.



Fig. 6. The occlusal surface of maxillary cheek teeth in an aged horse. Because equine cheek teeth taper toward their apices, spaces (diastemata) have developed between these aged teeth, which have then become filled with food. Note that the infundibulum is present in the tooth on the right side, but both infundibula are fully worn in the central tooth, with just some localized areas of peripheral enamel (arrowheads) remaining. The tooth on the left has been worn right down to its roots (cementum only) and is now in two parts, with just traces of peripheral enamel remaining on its buccal and palatal aspects (arrowheads). Because of wear of their peripheral and infundibular enamel folds, these aged teeth have now become smooth and hollowed out (i.e., senile excavation) and are of little use for grinding forage.

fully of cementum, i.e., they are simply enlarged roots, which by definition are enamel-free (Fig. 6). Being without enamel, they also have little resistance to wear and so are ineffective at grinding forage and are readily worn smooth and hollow and are further examples of senile “smooth mouth.”

5. Incisors

In foals, the deciduous dentition contains three incisors in each quadrant. The deciduous central (01s), middle (02s), and corner (03s) incisors erupt at birth, 4–6 wk, and 6–9 mo, respectively. The deciduous incisors are smaller, whiter, and contain wider and shallower infundibula than their permanent successors, which usually erupt on their lingual aspect. The eruption of deciduous and permanent teeth incisors can be used to estimate the age of horses up to 5 yr old with a reasonable degree of accuracy. However, after that time, estimation of age by dental examination is unreliable, despite its traditional role for this purpose.^{3–6}

Adult horses have 12 incisors in total, 6 in each arcade. Incisors in younger horses are curved (convex on their labial aspect—concave on their lingual aspect) and taper in uniformly from the occlusal surface toward the apex (unlike brachyodont incisors that have a distinct neck). Therefore, with advanced aging and wear, spaces (diastema, pleural-diastemata) can develop between the incisors, which can trap food and be problematic in some

horses. The fully developed incisor arcade in a young adult horse has an almost semicircular appearance, which becomes gradually shallower with age, because of alteration of teeth shape caused by progressive wear. The occlusal angle between the upper and lower incisors also loses its curvature and decreases with age from almost 180° after eruption, to about 90° at 15 yr of age.

The infundibulum present in all incisor teeth is sometimes termed the “cup” or “incisal cup.” This funnel-like structure is almost circular in shape and in many horses is about 10-mm deep when the tooth first erupts. It is usually incompletely filled with cement and consequently, will later become filled with decomposing food material and appear dark. The depth of the infundibulum can vary greatly between horses, and thus, they may be often be worn away before, or more frequently many years after, the traditionally accepted times.³⁻⁵ When the infundibular cup is worn away, it leaves behind a small ring of infundibular enamel located on the lingual aspect of the occlusal surface, which is called the “enamel spot” (enamel ring or mark). Because of the slower wear of enamel compared with dentine, the enamel spot becomes elevated on the occlusal surface. In contrast to the upper cheek teeth infundibula, the incisor infundibula do not suffer infundibular caries.

The “dental star” represents exposure of secondary dentine (with a small central area of tertiary dentine)⁷ that has been deposited within a former pulp cavity on the occlusal surface of incisors. It appears sequentially in the 01s, 02s, and 03s (central, middle, and corner incisors) as a brown transverse line on the labial aspect of the occlusal surface. Because horses can have a variable height of primary dentine above the pulp cavity, this can lead to variation in the time of appearance of secondary dentine with this feature sometimes appearing in incisors 1-3 yr earlier than it is traditionally believed to occur.^{3,5} With further tooth wear, the dental star gradually becomes oval in shape and also moves toward the center of occlusal surface.

Other anatomical incisor features have also traditionally been used to age horses with variable degrees of accuracy. The occlusal surface is usually oval in recently erupted incisors, but with wear, they successively become round, triangular, and then oval in shape. These shape changes are more apparent in the 01s and 02s than in the 03s. Galvayne's groove is a longitudinal depression that allegedly first appears on the labial aspect of 103 and 203 at about 10 yr of age, is half-way down the clinical crown at 15 yr of age, and fully down by 20 yr of age. A “hook” (localized dental overgrowth) can develop on the caudal aspect of the occlusal surface of 103 and 203 at any time between 4 and 18 yr of age. It is caused by incomplete occlusal contact between the upper and lower 03s and is sometimes called a “7-yr hook” because it was traditionally (but erroneously) believed to always

appear at 7 yr of age. Other variations in incisor teeth appearance can also be because of individual and breed variation, differing environmental conditions, differing eruption times, and the presence of certain stereotypic behaviors such as crib-biting and wind-sucking.

6. Canine and “Wolf Teeth”

Male horses normally have four canine teeth (two maxillary and two mandibular) that erupt at 4-6 yr of age in the interdental space (between the incisors and premolars). They are simple brachyodont teeth (i.e., contain no coronal cement or enamel folding and have limited time of eruption). They are pointed teeth that are convex on their buccal borders but slightly concave on their medial (lingual and palatal) aspects. In the adult Thoroughbred, they are 5- to 7-cm long. Most of this tooth is unerupted crown (which does not erupt with age unlike the other hypsodont equine cheek teeth) and roots. The lower canines are usually more rostrally positioned than the upper, and thus there is normally no occlusal contact between the upper and lower canines. This is alleged to be a reason why the canine teeth (especially the lower) are prone to develop calculus. Occasionally, loss of surface enamel of canine teeth may also allow a build up of calculus. Canine teeth are usually absent or rudimentary in female horses.⁸

One or both of the upper first premolars, and less commonly, the lower first premolar, can also be present as the small, vestigial “wolf teeth” with a reported incidence of between 13% and 32% by different authors. This in fact may be underestimated because many young horses may lose their “wolf teeth” when they shed their deciduous first cheek teeth (Triadan 506 and 606).^a The majority of small wolf teeth lying in their normal opposition (directly in front of the 06s) cause no harm in the author's opinion, despite the fact that many clinicians have very strong views to the contrary. If “wolf teeth” are very large, particularly if displaced rostrally, medially, or laterally, they can interfere with a bit, or the cheeks or lips may be pressed against these teeth by tack, causing oral discomfort.

7. Cheek Teeth

An adult equine mouth normally contains 24 cheek teeth, forming four rows of 6 teeth that are accommodated in the maxillary and mandibular bones. The cheek teeth act as grinders, using a rotary, crushing, and side-to-side movement, of one side of the mandible at a time. This main rotary movement is combined with a slight rostro-caudal (back to front) movement of the temporo-mandibular joint; the latter movement also occurs during lifting and lowering of the head. Consequently, small overgrowths may develop on the rostral aspect of the first maxillary cheek teeth (106 and 206) and the caudal aspect of the sixth mandibular cheek teeth (311 and 411) in horses with a slight rostral dis-

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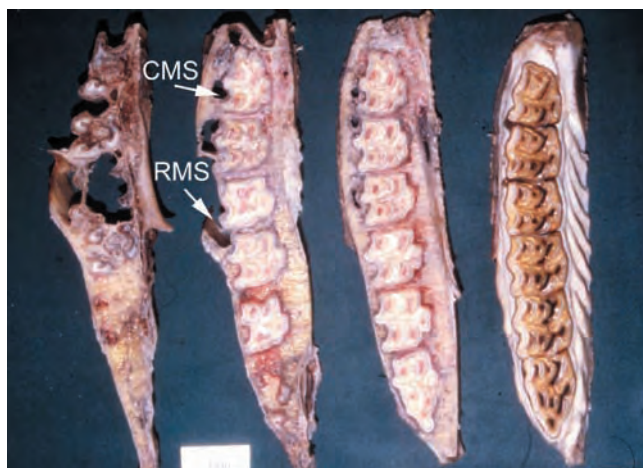


Fig. 7. Longitudinal section of a normal equine maxilla. Note the triangular shape of the first and last cheek teeth, with the other four teeth having a squarer appearance. Five pulp cavities are present in the second through fourth cheek teeth with six pulp cavities present in the first and sixth teeth. Although all these teeth are in contact at the occlusal surface, spaces are present between them more apically, caused by the decreased cross-sectional areas of the more apical aspect of the reserve crown. The angulation of the first and the fifth and sixth teeth also contributes to these spaces. In this particular horse, the caudal aspect of the third cheek teeth and all of the fourth through sixth cheek teeth lie within the rostral (RMS) and caudal (CMS) maxillary sinuses.

placement of the upper jaw in relation to the lower jaw that might not occur if they were fed from ground level. Such cases also usually have a developmental incisor overjet, i.e., “parrot mouth.”

Cheek Teeth Shape and Dimensions

On transverse section, equine cheek teeth are rectangular shaped, except the first and sixth (06s and 11s), which are somewhat triangular shaped. The upper cheek teeth are wider and relatively square on cross-section (Figs. 3 and 7) compared with the more rectangular shape of their narrower mandibular counterparts (Figs. 2 and 8). The lower cheek teeth have a taller erupted crown than the maxillary cheek teeth, with the latter often having just a few millimeters of crown exposed on their palatal aspect. This latter feature becomes significant when trying to orally extract maxillary cheek teeth. All of the teeth are relatively straight in the longitudinal plane, except the sixth, and to a lesser extent, the first and fourth cheek teeth, which have curvature of their reserve crowns and roots to compress the cheek teeth rows together at their occlusal aspect.

The first cheek teeth (06s) are the shortest (about 5-cm long in young Thoroughbreds), with the remaining teeth in this breed up to 7- to 8-cm long before wear. All equine permanent cheek teeth are in wear by 5 yr of age. Because they wear at about 2–3 mm/yr, a 75-mm-long tooth should be fully worn by about 30 yr of age. Once fully developed, all the

upper cheek teeth have three roots (two small lateral and a larger medial) and the lower cheek teeth possess two roots, one rostral and one caudal (except 011s, which have three). The roots of mandibular cheek teeth tend to be longer than those of their maxillary counterparts

Anisognathia

In normal horses, the distance between the maxillary cheek teeth rows is a median 23% wider than that between the mandibular rows,^b a feature that is termed anisognathia (Fig. 9). This is in comparison with human teeth that are equally spaced (isognathic). Additionally, the maxillary cheek teeth are wider than their mandibular counterparts. Consequently, when the mouth is closed, approximately one-third of the occlusal surface of the upper cheek teeth are in contact with about one-half of the lower cheek teeth's occlusal surface. This anatomical feature makes radiographic examination of the cheek teeth by dorso-ventral radiography very difficult.

Curvature of the Cheek Teeth Rows in the Latero-Medial (Lingual/Palatal-Buccal) Plane

The rows of both the maxillary and mandibular cheek teeth form slightly curved rows. This is more pronounced in the maxillary rows, whose buccal aspect is convex (Fig. 7). This feature makes it impossible to properly float all of the upper cheek teeth with straight handled floats. The lower cheek teeth rows may be slightly curved in the lingual plane, a feature that should not be mistaken as the present of (mild) cheek teeth displacement.

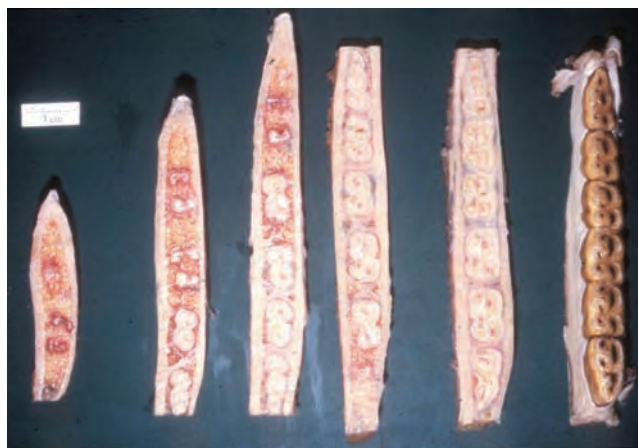


Fig. 8. Longitudinal section of a normal equine hemimandible. Note again the triangular appearance of the first and sixth mandibular cheek teeth, with the mandibular teeth between these being more rectangular in appearance. While all teeth are close together at the occlusal surface, note again, spaces developed between the more apical aspects of these teeth, caused in part by the smaller size of the reserve crown. The unerupted crown has limited peripheral cementum, unlike some of the previous examples of erupted (clinical) crown, where large amounts of cement substantially contribute to bulk of the tooth.

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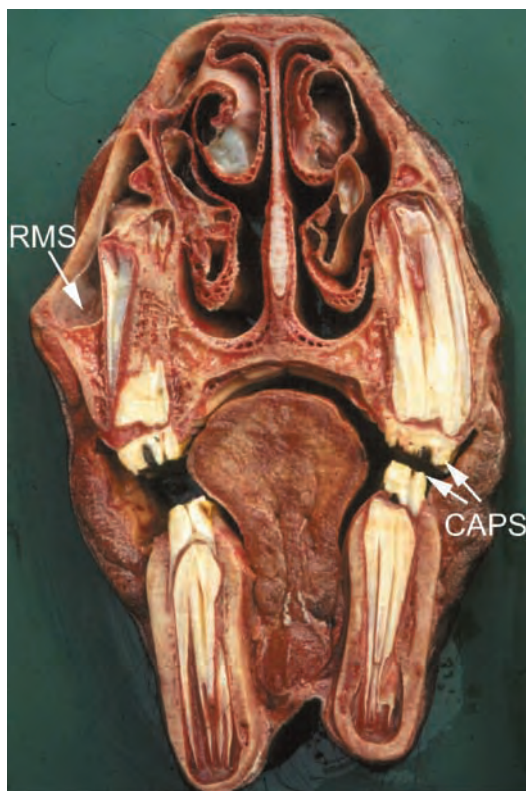


Fig. 9. Transverse section of a young equine skull at the level of the third cheek teeth. This section shows part of the 108 lying in the rostral maxillary sinus (RMS). Note the thin maxillary bone between the medial aspect of the alveolus and the nasal cavity on 208, yet inexplicably, most apical infections of these teeth drain externally, through the thicker bone. Note the wider distance between the rows of upper compared with lower cheek teeth and the normal angulation of the occlusal surface (*circa* 15°) of these temporary teeth.

Lateral Ridges of the Upper Cheek Teeth

The upper cheek teeth have lateral ridges, i.e., vertical protrusions of the teeth, some which can be very large in individual horses. If prominent and

sharp at their occlusal aspect, (i.e., “enamel overgrowths,” “enamel points”), these ridges can cause buccal damage. Even permanently outdoor domestic horses without supplementary feeding can have very prominent and sharp lateral ridges, especially on their (upper) 10s and 11s, with associated buccal ulceration of unknown clinical significance. Wild Equidae do not have such enamel overgrowths.⁹

Angulation of Occlusal Surface

The occlusal surfaces of the cheek teeth are parallel to each other (like brachyodont teeth) at eruption. Later, both because of the above noted anisognathic jaw conformation and the medial direction of the “power stroke” of equine jaw movement, the occlusal surfaces become angled at 10–15° (sloped from dorsally on lingual/palatal aspect to ventrally on buccal aspect). If horses are fed high levels of forage (grass, hay, silage) in their diet, they will increase the distance of the lateral “power stroke” of mastication and so keep this occlusal angle shallow. If however, they are fed high levels of concentrates, in addition to masticating for less time, the vertical or “crushing stroke” of mastication will increase and the lateral masticatory action decreases. Subsequently, these teeth will develop “enamel points” and later may develop increased angulation of the occlusal surface to, e.g., 45°. This latter feature will also mechanically restrict the normal side-to-side lateral jaw movements in a vicious self-perpetuating cycle, causing the disorder of “shear mouth.”

Transverse Ridges of Occlusal Surface

About 12 transverse ridges are also present on the occlusal surface of both the upper and lower cheek teeth, which are most prominent in young horses (Fig. 10). These ridges, which interdigitate with ridges on the opposing tooth, are related to the occlusal cusps and crests (wear facets and wear reliefs), which are caused by the enamel infoldings along the crown. Their function is to increase the surface area of the occlusal surface of the cheek



Fig. 10. Sagittally sectioned equine skull. This hemisected skull of a young adult horse has a mild curve of Spee. These teeth also have pronounced but normal transverse ridges, which in such a case should *not* be termed exaggerated ridges and should not be reduced in size or removed.

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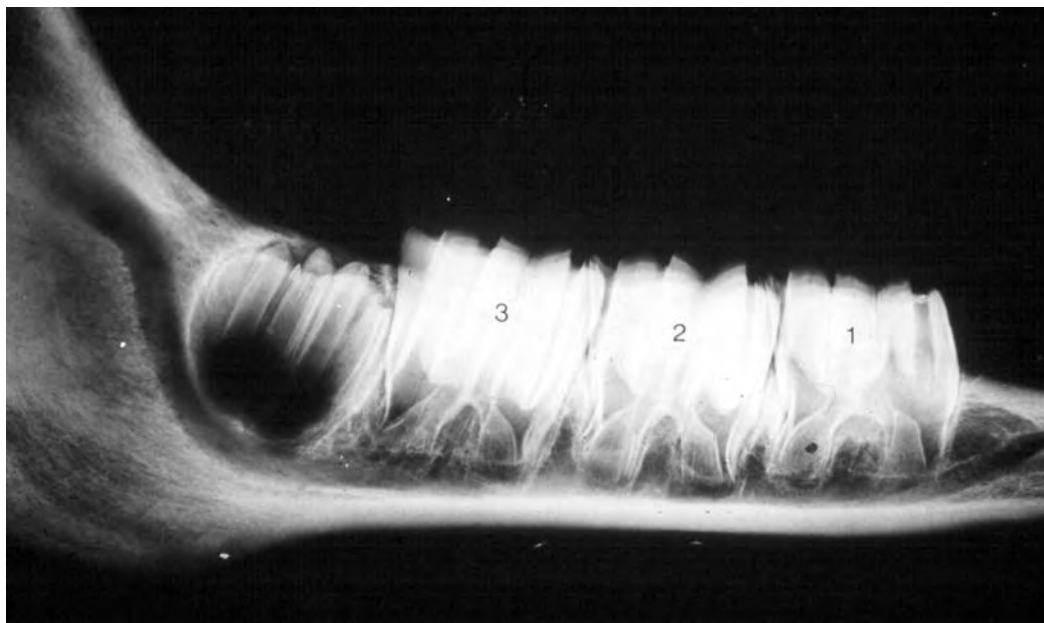


Fig. 11. Lateral radiograph of the hemimandible of a 4-mo-old foal. There is not yet enough room for the developing bud of the first permanent cheek tooth (i.e., fourth cheek tooth; Triadan 09) to erupt. Toward the occlusal surface, partially calcified enamel folds of this developing fourth cheek tooth are identifiable. Apically, there is still much growth, and later, calcification of this tooth bud to occur. Note the tight compression of these four cheek teeth with the developing fourth tooth tilting the third deciduous cheek tooth (3) in a rostral direction. The buds of their permanent successors are becoming apparent beneath the three deciduous cheek teeth (1–3). Reproduced with permission from Dixon PM, Copeland A. *Equine Veterinary Education* 1993, vol. 5, pp. 317–323.

teeth to allow more efficient grinding of forage. In some young horses these transverse ridges can be quite prominent and sharp. However, if they are all of equal size they should not be empirically reduced—this will just decrease the life span of the tooth. If however, individual transverse ridges are greatly taller than the remaining transverse ridges, they may then be termed exaggerated transverse ridges (ETRs). These tall ridges may prevent the normal, but limited, rostro-caudal mandibular movement. If allowed to progressively increase, individual exaggerated transverse ridges possibly may lead to “wavemouth,” i.e., irregularity of occlusal surface in the rostro-caudal plane. There is a need for critical studies to define what constitutes a normal and an abnormal transverse ridge.

Further anatomical predispositions to the development of “wavemouth” are unequal times of eruption of the permanent cheek teeth, with the cheek teeth that erupt first gaining an advantage that they maintain and increase throughout life. Becker suggests that the upper 09s can erupt 3 months ahead of the their lower 09 counterparts leading eventually to a position of “wavemouth.”⁹

Compression of Cheek Teeth Rows

All of the teeth in the (complete) dental arch of omnivores and carnivores are maintained in contact at the occlusal surface by being compressed together by pressure from the rostrally angled, caudal molar (termed a “wisdom tooth” in humans). However,

the presence of the interdental space (“bars of the mouth”) in horses necessitates the rostral cheek teeth to face caudally, helping to compress the occlusal aspect of each row of six cheek teeth together. Consequently, the clinical (erupted) crowns of the first equine cheek teeth (06s), both upper and lower, are angled slightly caudally. The crowns of the second, third, and fourth cheek teeth (07s–09s) are roughly vertical and the clinical crowns of the fourth and sixth cheek teeth (10s and 11s) are angled rostrally. Pressure from the (caudally facing) first (06s) and the (rostrally facing) caudal two cheek teeth (10s and 11s) tightly compress all the cheek teeth together at the occlusal surface. This factor allows the whole row of six cheek teeth to act as a single functional unit (Figs. 11–13).

Inadequate Compression of Cheek Teeth Rows

Continued eruption of these angulated cheek teeth maintains this tight occlusal contact throughout life in the normal horse. This is despite the fact that equine teeth slightly taper in toward their apex, and otherwise with aging, they would develop spaces between the teeth (interproximally) that is termed diastema(ata). Many old horses (>20 yr old) do develop diastema between their cheek teeth, where it can lead to food accumulation between the teeth and the adjacent periodontal space, leading to variable degrees of periodontitis. Diastema is also a major developmental disorder that occurs in some

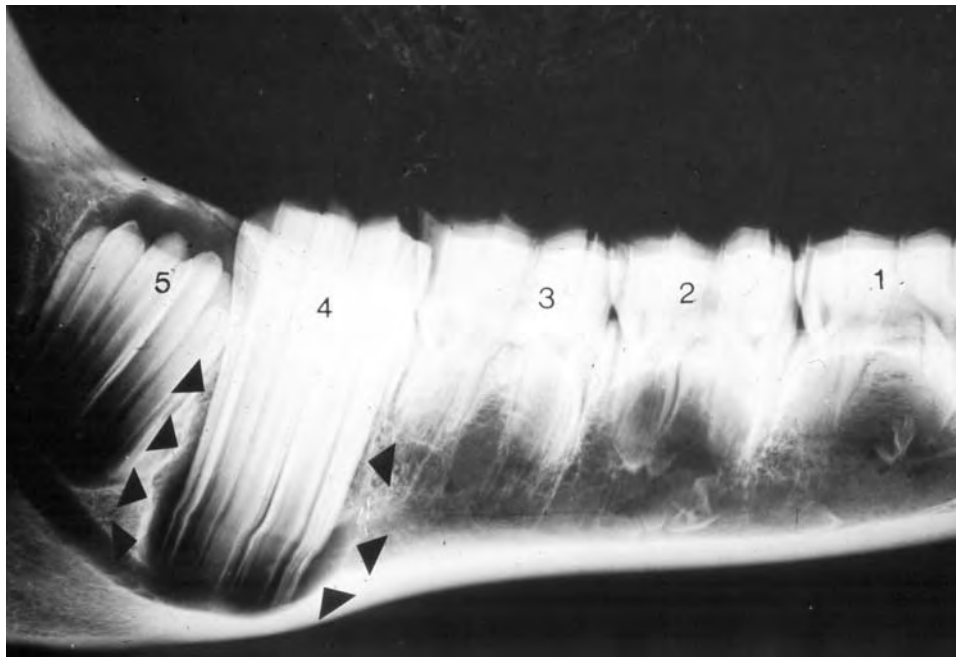


Fig. 12. Lateral radiograph of the hemimandible of a 15-mo-old horse. This radiograph shows the fourth cheek tooth (4) to be fully erupted, with the developing fifth cheek tooth (5) caudal to it. A large eruption cyst (arrowheads) is still present around the apex of the still developing fourth cheek tooth, which has a very wide periodontal space (space between the apex of the tooth and the lamina dura denta of the alveolus). The fourth cheek tooth possibly has been overcrowded during its development and eruption because it has buckling of the enamel folds of its apex, which must have occurred before calcification. The buds of the developing first through third permanent cheek teeth are prominent beneath their deciduous precursors (1–3). Reproduced with permission from Dixon PM, Copeland, A. *Equine Veterinary Education* 1993, vol. 5, pp. 317–323.

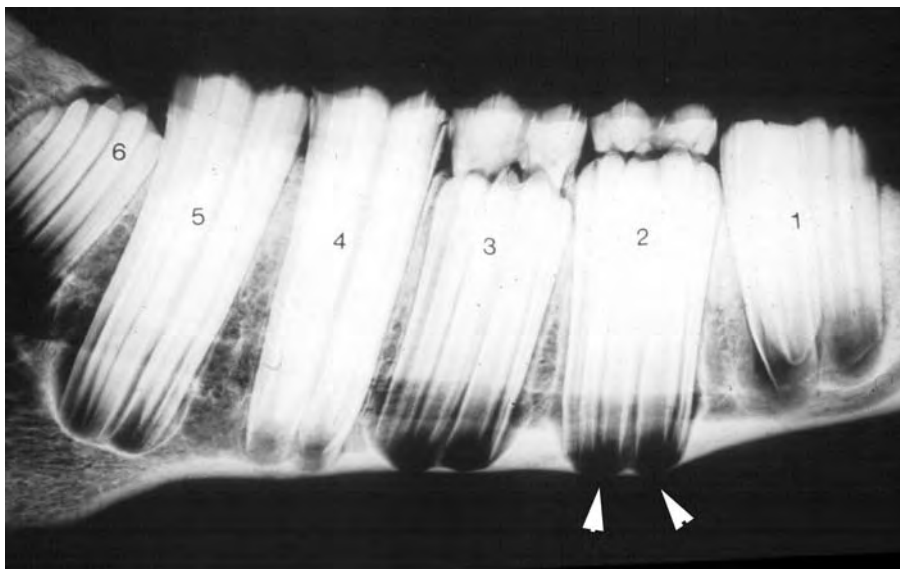


Fig. 13. Lateral radiograph of the hemimandible of a 27-mo-old horse. The first (1) and fifth (5) permanent cheek teeth have erupted. The second (2), and to a lesser extent, the third (3) permanent cheek teeth are well developed, with the remnants of their deciduous precursors ("caps") sitting on them. There is not yet enough room for the sixth permanent cheek tooth (6) to erupt, but within 15 mo or so, further elongation of the mandible would have allowed this tooth to erupt normally. Note that the first cheek tooth is the shortest. There are variably sized eruption cysts beneath the apices of the developing second and third permanent cheek teeth. The ventral aspect of the mandibular cortex has become thin and deviated ventrally (arrowheads) to accommodate these eruption cysts and their underlying large dental apices.

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young horses because of inadequate angulation of the rostral and caudal cheek teeth, leading to inadequate compression of the cheek teeth rows.¹⁰ It can also developmentally occur in horses that have adequate cheek teeth angulation, but where the cheek teeth buds develop too far apart. In both cases, deep food impaction can occur leading to severe oral pain with quidding caused by deep periodontal disease that can even lead to widespread osteomyelitis of the mandible and maxilla.

Excessive Angulation of Cheek Teeth Rows

On the other hand, excessive angulation of the cheek teeth may cause undue compression along the occlusal aspect of the cheek teeth rows. This may lead to mechanical difficulty in dental eruption, i.e., excessive angulation or pressure at the occlusal area from the two adjacent teeth can mechanically impede eruption of the tooth between them by causing a vertical impaction.¹¹ This may be the cause of the eruption cysts visible on the ventral aspect of the mandibles and dorso-lateral aspect of the maxillae in some 3- to 4-yr-old horses during the eruption of their permanent second and third (07s and 08s) cheek teeth. Interbreeding of horses with anatomically shallow jaws with horses that have very long-crowned cheek teeth may also be a cause of these eruption cysts; which by unknown mechanisms, may even lead to their infection, (i.e., an apical infection) in some young horses.

Anatomical Predispositions to Cheek Teeth Overcrowding

There is also a critical relationship between the length of the jaws and the lengths of the cheek teeth rows in horses. In the newborn foal, the three cheek teeth present completely fill the full length of the jaws. In contrast to brachyodont teeth and also to equine incisors, the transverse (cross sectional) area of equine deciduous cheek teeth is quite similar to those of adult teeth, as recognized by trying to differentiate between a permanent cheek tooth and a deciduous cheek tooth remnant ("cap") in some horses. In contrast, the smaller equine deciduous incisors are readily differentiated from their permanent counterparts. At 1 yr of age, there is normally just enough room for the fourth cheek teeth (09s—the first permanent cheek teeth) to erupt (Fig. 11). If however, there is premature eruption of the fourth cheek tooth or delayed development of jaw length, the erupting tooth will not have room to erupt normally and it will become displaced, to either side, causing a major, life-long dental problem.¹⁰ Similarly, the fourth cheek tooth can become overcrowded and displaced at 2 yr of age, leading to similar serious problems. By the time the sixth cheek tooth (011s) erupts at about 3.5 yr of age, full growth of the jaws has usually occurred and developmental cheek teeth displacement of 11s is rare, although *acquired* displacement of the sixth mandibular cheek teeth (311 and 411) can occur.¹⁰

Age-Related Changes in Length of the Cheek Teeth Rows

As noted above, the tapering in of the cheek teeth toward their apices (Fig. 6) can cause diastemata. The age-related decrease in the lengths of the cheek rows may not be equal between rows, thus leading to unilateral or bilateral rostral (06s) or caudal (011s) overgrowths of the upper or lower cheek teeth.

Facial Asymmetry

Horses with "wry nose," which is an obvious facial deformity, will have uneven wear on their incisors and cheek teeth. However, other horses have more subtle degrees of this deformity that also will cause the development of an oblique incisor occlusal surface ("slopemouth" or "slantmouth") along with a rostral 06 and caudal 011 overgrowths, usually on *one* side of their mouth. Other horses with parallel rows of cheek teeth may have developmental disparities in the length of opposing rows, leading to various combinations of 06 and 11 overgrowths, similar to those noted in the previous paragraph.

"Curve of Spee"

The occlusal surface of the rows of cheek teeth are not level as occur in some other species; instead, the surface of the last three cheek teeth curve upward in the caudal direction ("Curve of Spee"; Fig. 10). This curvature is most marked in Arab-type breeds, which often have a similar curvature on their (dished) nasal and frontal bones. A marked curve of Spee can also be present in some other smaller breeds. It is important that during oral examination, this normal feature is not mistaken as an overgrowth of 311 and 411, which if mistakenly "reduced," will expose their pulp cavity. It is useful to palpate the distance between the upper margin of the gum and the occlusal surface of 310 and 410, and then of the 311 and 411 to judge in this way if the 11s are really overgrown.

Relationships of Cheek Teeth Apices to Their Supporting Bones

The alveoli of the rostral upper cheek teeth (06s and 07s) and sometimes the rostral aspect of the 08s (and occasionally even the 09s) are embedded in the rostral aspect of the maxillary bone (Fig. 9). Eruption cysts (even focal bone lysis) also commonly occur in the maxillary bone overlying the apices of these teeth at 3–5 yr of age, but because of the presence of overlying levator nasolabialis and levator labii superioris propria muscles, they are not as easily detected as the obvious equivalent mandibular "swellings" (i.e., 3- and 4-yr "bumps"). Infections of these rostral upper cheek teeth apices usually result in a swelling of the overlying maxillary bone and possibly an external sinus tract; less commonly a sinus tract will develop into the nasal cavity.¹¹

It is generally stated that the apices and reserve crowns of the caudal three to four cheek teeth (08s–11s) lie in the rostral and caudal maxillary sinuses.

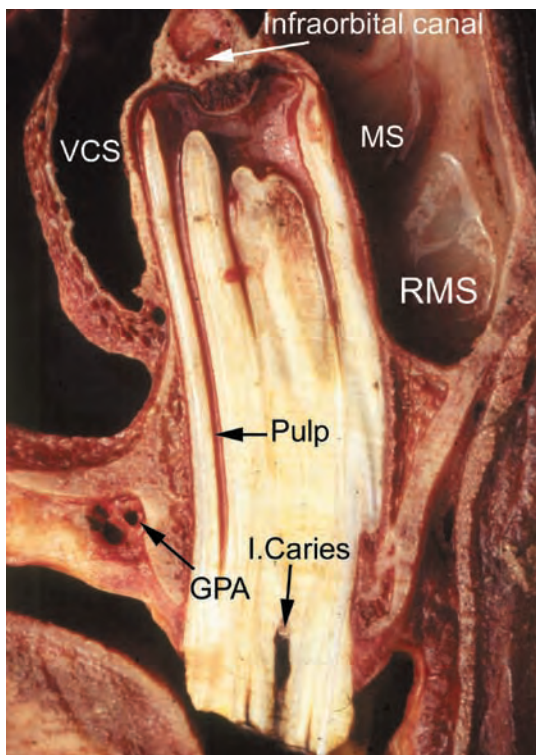


Fig. 14. Transverse section of an equine skull containing a maxillary cheek tooth. This maxillary cheek tooth is lying in the rostral maxillary sinus. Note the ventral conchal sinus (VCS) on its medial aspect and the rostral maxillary sinus (RMS) laterally. The maxillary septum (MS) can be identified dorso-caudally, as can the infraorbital canal (IOC) dorsally and the large greater palatine artery (GPA) on the palatal aspect of this tooth. Note the wide, open apex of this maxillary tooth with large interconnecting pulp chambers. All of these pulp horns are healthy, with the most palatal of its pulp horns transversely sectioned just a few millimeters beneath the occlusal surface. Note the presence of a patent infundibulum, which has some central infundibular cemental caries (I. caries) (arrow), and the oblique angle of the occlusal surface of this tooth.

However, there is considerable variation between horses, with the rostral aspect of the rostral maxillary sinus varying from being level with the middle of the second to the middle of the fourth cheek tooth and the maxillary septum varying in position from overlying the caudal aspect of the third to the caudal aspect of the fourth cheek tooth.^c

In young horses, the large reserve crowns occupy much of these sinuses (Fig. 14), but with age and subsequent eruption of their reserve crowns and simultaneous retraction of their alveoli, the maxillary sinus cavities increase in volume. This intimate relation between the cheek teeth and sinuses allow periapical infections of the third through sixth cheek teeth to cause maxillary sinus empyema. The apices of the lower cheek teeth are embedded in the mandible and occupy most of this bone in younger horses. With mandibular cheek teeth apical infections (usually in young horses) the adjacent

ventral aspect of the mandible will become focally swollen and possibly develop a sinus tract.

8. Alveolar Bone

Alveolar bone is very flexible and constantly remodels to accommodate the changing shape and size of the dental structures it contains. Alveolar bone contains a thin layer of compact bone that lines the alveolus proper (in which Sharpey's fibers insert) that is radiographically termed the lamina dura (lamina dura denta). This area is radiographically detectable as a thin, radiodense line in brachyodont teeth, peripheral to the radiolucent periodontal space. However, because of irregularities of the periphery of some normal equine cheek teeth, the lamina dura denta is not always clear on radiographs. Histologically, the equine lamina is much more irregular than brachyodont alveolar bone, possibly caused by the constant remodeling associated with prolonged eruption.^d

Radiographic features of apical infection include widening of the periodontal space and irregularity or even local loss of the lamina. However these are also radiographic features of the normal developing apex of an equine cheek tooth (Figs. 11–13). Because this is a time when apical infections often occur, especially in mandibular cheek teeth, this leads to difficulty in radiographic diagnosis of apical infection in this age group. The remaining alveolar bone surrounding the lamina cannot be differentiated from the remaining bone of the mandible or maxilla. The most prominent aspect of the alveolar bone beneath the gingival margin is termed the alveolar crest.

9. Enamel

Enamel is the hardest and densest substance in the body. Because of its high (96–98%) mineral content it is almost translucent in appearance and it gains its color from the underlying dentine. In equine teeth, the peripheral enamel is covered by the chalk-like peripheral cement, which on the clinical crown may become discolored on some diets. This cement is often worn away on the rostral aspects of the incisors, thus exposing the underlying, white, shiny enamel. Because mature enamel is almost pure mineral and contains no living cells, it can therefore be regarded as an inert or “dead” tissue. Additionally, because the ameloblasts (enamel-producing cells) die off once the tooth is fully formed, enamel cannot repair itself. Enamel is almost fully composed of pure hydroxyapatite crystals, which are larger than the hydroxyapatite crystals of dentine, cement, or bone. These crystals are arranged both into structured enamel prisms and also into less structured interprismatic enamel. Enamel can be classified into different types depending on the shape of the prisms and arrangements of prismatic and interprismatic enamel.

Equine teeth are primarily composed of two main types of enamel, i.e., equine type-1 and type-2

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Fig. 15. Electron microscopy of equine type-1 enamel. Note the parallel orientation of the solid interprismatic plates of enamel with interspersed rows of enamel prisms of equine type-1 enamel. These parallel, structural lines make this enamel more likely to mechanically fracture, although it is a very hard enamel.

enamel.¹² Equine type-1 enamel is composed of parallel layers of enamel prisms and flat interprismatic enamel plates (Fig. 15). The presence of interprismatic enamel plates makes this type of enamel very hard but brittle. The cheek teeth, especially the upper cheek teeth, are mainly composed of equine type-1 enamel, which allows them to resist the high, repetitive forces of masticating food for up to 20 h/day. In contrast, equine incisors are mainly composed of equine type-2 enamel. This type of enamel is composed solely of groups of enamel prisms that are intricately interwoven in “spaghetti-like” bundles in three dimensions (Fig. 16), which makes it very resistant to cracking, although not as hard-wearing as equine type-1 enamel.

Consequently, equine incisors that are subjected to massive shearing forces when prehending food (e.g., a horse pulling hay from a tight hay net) and that also have little lateral support (unlike cheek teeth), rarely fracture. Incisors do not require to be very hard because they do not grind food. In contrast, the cheek teeth, although very resistant to wear, are susceptible to develop “idiopathic” fractures, some of which may involve fractures of equine type-1 enamel.¹³ These fractures mainly occur in the upper cheek teeth—despite them having much *thicker* enamel than the lower cheek teeth. However, in other cases, such idiopathic cheek teeth fractures may occur because of separation of the junction between dentine and equine type-1 enamel or through pulp canals.^e As later discussed, the in-

fundibula may be involved in other spontaneous and pathological dental fractures.

The total surface of the equine incisors is less than 8% of the occlusal surface of the cheek teeth, in addition to the incisors being composed of softer enamel than cheek teeth. Consequently, the practice of routine incisor reduction procedures, purportedly to reduce “overgrown” incisors that are keeping the cheek teeth out of occlusion cannot be justified from an anatomical viewpoint.¹⁴

10. Dentine

The bulk of the mature equine tooth is composed of dentine, a cream colored, calcified tissue composed of approximately 70% minerals (hydroxyapatite crystals) and 30% organic fibers, mucopolysaccharides, and water. The latter content is obvious in dried equine dental specimens where the dentine (and also cement, and to a lesser extent, enamel) will develop cracks. Because equine primary dentine contains very high levels of heavily mineralized peritubular dentine, it too is somewhat translucent. The mechanical properties (including tensile strength and flexibility) of dentine are highly influenced by the relationship and arrangements of its collagen fibers and other organic components and minerals. In equine teeth, the presence of areas of more flexible dentine (and also of flexible cement) interspersed between the layers of hard but brittle enamel allows these softer calcified tissues to act as “crack stoppers.” The combined three calcified tis-

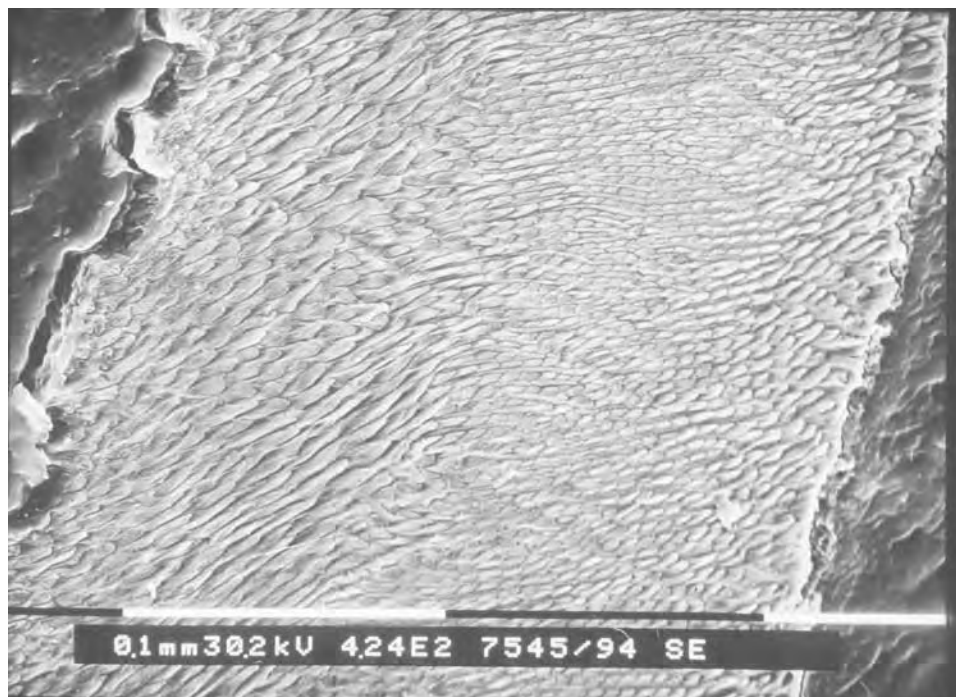


Fig. 16. Electron microscopy of equine type-2 enamel. This type of enamel contains no interprismatic plates, just bundles of enamel prisms, which, as can be seen, are oriented in many different directions. This prism orientation reduces the possibility of stress fractures occurring in equine type-2 enamel. The absence of dense interprismatic enamel plates makes this enamel softer than equine type-1 enamel.

sues in the tooth resembles a biological “safety glass,” as well as creating the previously noted, irregular occlusal surface. This is exemplified in teeth with caries, e.g., advanced infundibular caries that will selectively destroy the softer cementum and dentine first, with pathological fractures then occurring in the remaining unsupported enamel.

Different Types of Dentine

Dentine can be divided into three main types, primary, secondary and tertiary dentine. A thin layer of primary dentine is already laid down in the recently erupted tooth. Regular secondary dentine is progressively laid down over the life of the tooth by the layer of odontoblasts that line the periphery of the pulp and so secondary dentine gradually replaces pulp over the life of the tooth. The young equine cheek tooth is largely composed of an enamel skeleton surrounded by peripheral cementum and containing some primary dentine and a very large pulp cavity and thus is very brittle. Such teeth are very easy to rasp (float) but are very liable to fracture. Consequently, some clinicians recommend that equine cheek teeth under 10 years old should never be cut with “dental shears”. In any case it is much safer to gradually and controllably reduce large overgrowths with solid carbide blades or with motorized dental tools, in horses of all ages.

Secondary Dentine and Pulpal Exposure

Because of the intimate association between the pulp and dentine that act as a single functional unit,

the term pulpo-dentinal complex is often used for these two tissues. The constant deposition of secondary dentine in equine teeth normally prevents pulpar exposure on the occlusal surface as it is worn away because of normal attrition. However, if there is an imbalance between the rate of wear on the occlusal surface and the rate of secondary dentine deposition at the coronal aspect of the pulp, pulpar exposure can occur. The stimulus for laying down secondary dentine in the pulp cavity of equine teeth is not fully understood. Much deposition no doubt will be of a continuous nature on a “biological clock” basis. However, some secondary dentine deposition may also be induced by stimuli from the adjacent occlusal surface, i.e., mechanical, chemical, or thermal stimuli transmitted through the odontoblasts processes that inexplicably seem to lie exposed on the occlusal surface of the dentine of normal equine cheek teeth (Fig. 17).¹⁵ In humans, any exposure of odontoblasts processes is defined as pulpar exposure and is associated with pain.

This latter finding is of clinical significance after rasping (floating) of cheek teeth, where dentine (as opposed to overgrown enamel ridges) is rasped, because this can extensively disrupt the occlusal dentine and deeply expose odontoblasts processes.^f After extensive dental rasping, it is not unusual for some horses to have oral pain (i.e., quidding forage) for some days (occasionally in individual horses for weeks), which is often empirically attributed to “temporomandibular joint pain,” when in fact, pul-

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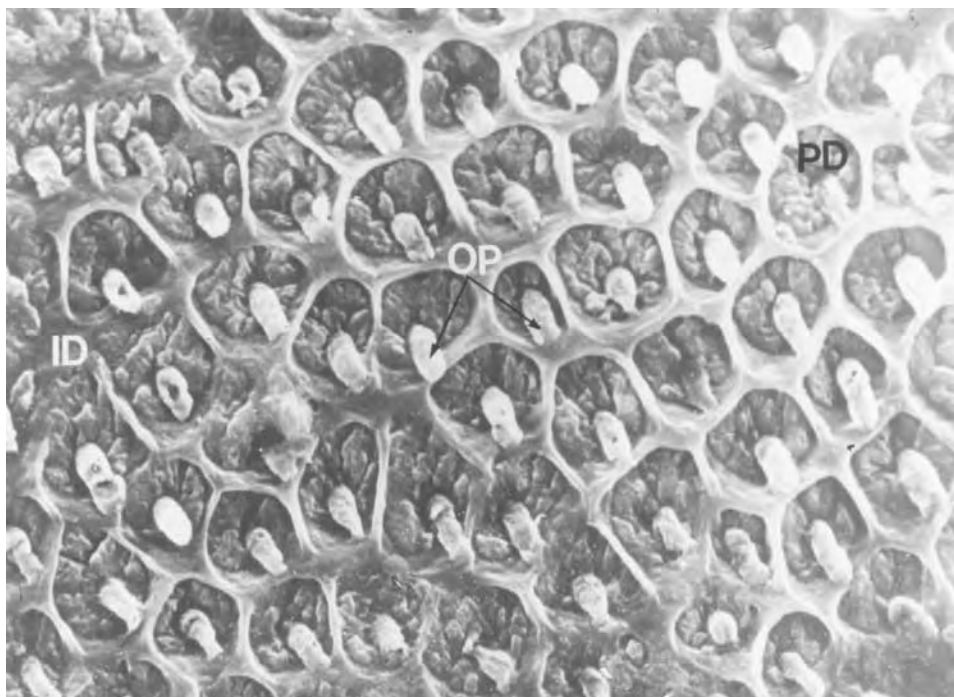


Fig. 17. Occlusal surface of primary dentine. The occlusal surface of this dentine shows odontoblast processes (OP) protruding from the dentine. In vivo, this occlusal surface would have been covered with an organic covering (pellicle). In humans, such odontoblast process exposure on the occlusal surface would result in pulpar pain and possibly pulpar infection with loss of the affected tooth. PD, peritubular dentine; ID, intertubular dentine.

par pain caused by damage to dentine and deep exposure of odontoblast processes leading to pulpal inflammation may well be the cause. Perhaps antibiotic rather than analgesic therapy should be considered in the latter severe cases of post-floating oral pain.

A compounded situation exists where, because of loss of a cheek tooth, a large (e.g., >20-mm-high) overgrowth ("stepmouth") is allowed to develop on the unopposed cheek tooth. Not only will this tooth not undergo any occlusal wear, but because of lack of occlusion, it will also erupt more quickly than a normal tooth ("supraeruption"). Consequently, much of the pulp in the overgrown part of the crown may not have been replaced with secondary dentine. Attempts to reduce such overgrown teeth to the level of the remaining teeth may expose pulp and risk causing an apical infection. Such problems are most likely to occur in older horses, which have small pulp canals and narrow apical foramina that can develop pulp ischemia if significant inflammation develops in the pulp, caused by compression of the small blood vessels at the apical foramina.

Because of the progressive laying down of extensive secondary dentine that eventually replaces almost all of the pulp cavity, older equine cheek teeth have a hard and solid, ivory-like appearance, are hard to rasp, and are unlikely to fracture when cut with dental shears. In contrast to the almost translucent primary dentine, the less mineralized secondary dentine

has a dull opaque appearance. Additionally, it absorbs pigment from pigmented foods such as grass, which gives it a brown color that is obvious in the so called "dental star" in incisors or the five to six linear, brown areas of secondary dentine on the occlusal surface of cheek teeth that are in wear.

Repair of Dentine

Odontoblasts remain capable of synthesizing dentine throughout their lives if appropriately stimulated (unlike the situation with enamel). In young horses, which have a large and active pulp and wide vascular foramina into this pulp (Fig. 18), fracture of a tooth with pulpar exposure (i.e., termed a *compound* dental fracture) does not necessarily mean death of the pulp and inevitable loss of the tooth, as would be the situation with brachyodont teeth that have pulp exposure. The large vascular pulp and wide apical foramina of young equine teeth (both incisors and cheek teeth) can often resist the inevitable infection of exposed pulp from oral bacteria and then lay down specialized reparative dentine, which will seal off the exposed pulp from the microorganism filled oral environment. The tooth will then continue to erupt normally.

However pulpo-dentinal insults are more likely to cause pulpar death and possibly tooth loss in older horses. This is because older teeth have small pulp canals and apical foramina that can develop pulp ischemia if significant inflammation develops in the



Fig. 18. Transverse section of the hemimandible of a young horse. Note the very large pulp cavity caused by absence of secondary dentine in this young tooth. It has a very wide apex with a single large common apical foramen (arrowhead) and an intercommunicating common pulp. The remnants of the deciduous tooth ("cap") sit on this almost fully erupted cheek tooth.

pulp and compresses the small vasculature at the apical foramen. Pulpo-dentinal insults can vary from traumatic fracture of an incisor or excessive grinding (burring) of the occlusal surface of a cheek teeth, in both instances where pulp has become exposed, to less severe pulpar insults, e.g., thermal stimuli or exposure of odontoblast processes on the occlusal surface. The various types of reparative dentine have not been fully defined in the horse but include irregular secondary dentine laid down over larger areas to lower grade insults and tertiary dentine laid down in focal areas to marked insult.^g

11. Pulp

Pulp is a soft tissue within the dental pulp cavities that contains a variety of connective tissues, blood, lymphatic vessels, and nerves. Recently erupted cheek teeth have a large common pulp, but with age and deposition of secondary dentine, this becomes divided up into separate pulp horns. The presence of communicating pulp horns causes difficulties with endodontic treatment of young equine cheek teeth. There are six pulp horns in 06s and 11s and five pulp horns in the other four adult cheek teeth. In contrast, all incisors have a single pulp cavity. As noted above, the cell body of the odontoblasts lie adjacent to the unmineralized, developing dentine (predentine) at the periphery of the pulp, with their odontoblast processes extending out in the dentine

towards the periphery of the tooth, i.e., the junction of dentine and enamel (amelo-dentinal junction).

The use of many types of motorized grinding tools has been shown to greatly increase the temperature in equine pulp, to levels that would cause pulpar necrosis in humans.^g Care must be taken to prevent such damage when reducing large overgrowths with mechanized dental burrs. As the pulp is solely nourished by apical vasculature, apical infection (that usually destroys this vasculature) will cause pulp death. Because the periodontal ligaments (Sharpey's fibers) in most such cases remain viable (as exemplified by the enormous mechanical difficulty in extracting apically infected cheek teeth in young horses), the teeth will continue to normally erupt. Consequently, with further occlusal wear, but *without* further secondary dentine deposition (caused by death of the odontoblasts in the pulp), secondary pulpar exposure will now occur in all devitalized pulp chambers.

12. Cementum

Cement (cementum) is a white or cream-colored calcified dental tissue with mechanical characteristics and a histological appearance similar to bone, which is produced by cementoblasts. It contains about 65% inorganic (again mainly impure hydroxyapatite crystals) and 35% organic and water components. Like dentine, it is very much a living tissue, and its high organic content, including widespread collagen fibers, give it some flexibility. The cementoblasts are nourished by the blood vessels of the periodontal ligaments that attach the tooth to the alveolus. Cement and its periodontal membrane (ligament) can be considered as a single functional unit. In equine teeth, peripheral cement surrounds the entire crown and the deep infoldings particularly in the lower cheek teeth at eruption, and also fills the infundibula. Cement is the most adaptable of the calcified dental tissues and can be quickly deposited in response to insults such as infection or trauma, as can be seen by the large depositions of cement on the apices of some chronically infected equine teeth, sometimes even ankylosing the infected tooth to the alveolus and adjacent bone.¹¹

In brachyodont teeth, the main functions of cement are to provide anchorage on the tooth for Sharpey's fibers (that also attach to the alveolus) and to protect the underlying dentine at the dental apex. Recent work has shown that just as equine teeth emerge from the alveolus, there is a large surge in cementum deposition at this site^h to maximally contribute cementum to the structure and size of the clinical crown (Fig. 19) and possibly to help limit the development of diastema. However, as coronal cementum obtains its blood supply from the periodontal ligament and later the gingiva vasculature, these blood supplies are lost after eruption of the tooth above the gingival margin, and erupted coronal cement becomes inert. Cement deposition continues throughout the life of hypsodont teeth

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around the roots (root cement), contributing to the size and strength of the dental apex to compensate for crown wear with some old equine teeth being almost fully composed of root cement.

Infundibular Cement

During development, the infundibular cement is nourished by blood vessels of the gelatinous dental sac that fully surrounds developing teeth. After dental eruption, this soft sac is quickly destroyed by mastication. Consequently, infundibular cement has no blood supply after tooth eruption and no further cement can be deposited in the infundibulum. In many horses, the central part of the infundibular cement (upper cheek teeth) contains a defect at the site of their former blood vessels, which is usually asymptomatic (Fig. 20).^{16,17} Premature removal of deciduous “caps” will immediately cause

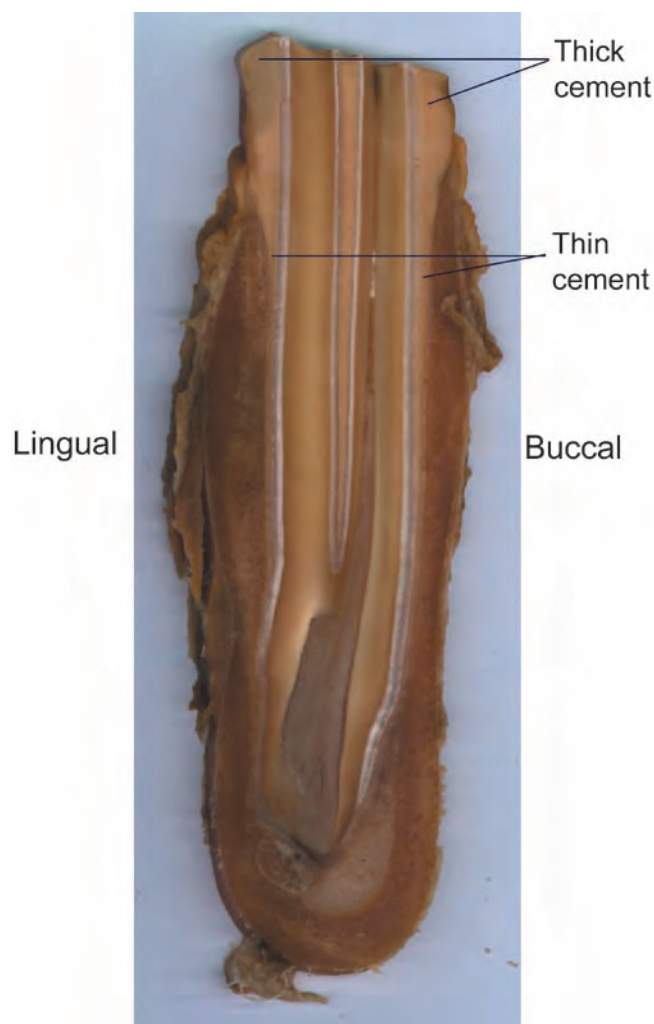


Fig. 19. Longitudinal section through 306 of a 4-yr-old horse. Note the major increase in peripheral cementum deposition that occurs just as the tooth emerges from the alveolus. This large amount of cement greatly contributes to the structure of the clinical crown.



Fig. 20. Transverse section of the infundibulum of an upper cheek tooth. The surrounding dentine (D), and the infundibular enamel (IE) and infundibular cement (IC) can be recognized in these two infundibula. This infundibulum on the left contains a large central defect in its cementum, i.e., central infundibular cemental hypoplasia with secondary cemental caries. The infundibulum on the right has no such defect. Figure courtesy of Mr. Ian Dacre.

the underlying gelatinous dental sac of the permanent tooth to be destroyed and the blood supply to the infundibular cement to be lost. This could potentially lead to larger central infundibular cemental hypoplasia (in the first three cheek teeth—which have deciduous precursors). This could lead to caries (dissolution of calcified tissues) and deeper food impaction. In some such cases, this caries can focally progress through infundibular enamel to the pulp and lead to apical infection.³ In other cases, advanced caries can weaken affected teeth and lead to the development of pathological (usually sagittal) fractures.

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