Physiology of Mastication

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Introduction

Some 50-70 million years ago, the *Equidae* family (*Hyracotherium*) first evolved. It initially had brachydont (short-crowned) dentition that was to adapt following climate changes and corresponding changes to its herbivorous diet.[1] There were also additional anatomical changes to its large intestine to allow microbial digestion of cellulose. This change to a coarser, more abrasive and fibrous diet necessitated the development of more complex teeth to grind this tough food. These primitive horses also developed infundibular enamel cups in incisors and maxillary cheek teeth (CT) thus resulting in a more complex occlusal surface. Incisors became specialised for efficient cropping of forage for prolonged periods of grazing of up to 18 hours per day.[2,3] Occlusal crown wear of the cheek teeth during such long grazing periods is usually reported to be 2-3mm per year in the modern horse, however, crown loss may actually be as high as 7-8mm per annum.[4]

Other dental adaptations to dietary changes included a progressive increase in crown length with prolonged eruption over the life of the horse (i.e. they became hypsodont, with development of long reserve crowns), and the presence of cementum peripheral to crown enamel because of such prolonged eruption.[1,5,6] Cementum also contributes significantly to the structure of the equine cheek teeth clinical crown.[6] Apposition of the three calcified dental tissues (cementum, dentine and enamel) with differential wear rates, allows the irregular CT occlusal surface to continually 'self-sharpen' during mastication. The harder enamel ridges protrude above the softer dentine and cementum on the occlusal surface.[1,7] Additionally, all the CT (except the first premolar – that became vestigial or absent in the domestic horse) came into full apposition (with the premolars resembling molars) allowing even more efficient lateral grinding of all cheek teeth during mastication.

Normal Dental Wear and the Necessity for Prophylactic Equine Dentistry

Occlusal wear is a function of multiple physical features including the amount and direction of forces between the two occlusal surfaces [attrition] - that can be modified with painful dental disease, the length of time spent chewing, the nature of the material being chewed and the physical characteristics of the teeth, i.e. whether pathological changes are present in them (e.g. infundibular cement hypoplasia or caries).

Different feeding regimes may also influence dental characteristics. Studies by Leue (1941) showed that differing types of food changed the degree of lateral excursion of CT

during mastication.[8] Horses fed concentrates had an increased vertical crushing component in their masticatory cycle, with a decreased lateral excursion when compared to horses fed hay. Those fed grass had intermediary lateral jaw excursion. Because of their high calorific content, diets high in concentrates reduce the length of time a horse masticates its food and so further predisposes the horse to overgrowths from decreased dental attrition.[3,9-11] In one study, feeding maize oil as a high energy replacement for oats reduced daily fibre intake,[12] thereby reducing to an even greater extent the amount of 'expected' normal dental attrition rather than if the horse had been in its 'natural' environment, i.e., grazing savannah. Replacing the oats with sugar beet pulp however had the opposite effect, increasing daily fibre.

Horses fed hay spend longer masticating compared with horses fed a high concentrate/cereal diet (Table 1). One study found horses and ponies to chew hay 58-66 times per minute, taking 4200 chews /kg dry matter[3] compared to a second study with horses at grass masticating at 100-105 times per minute.[13] This agrees with Leue's findings of increased lateral excursion (i.e. a slower, longer more deliberate masticatory cycle) being necessary to adequately masticate boluses of hay as compared to concentrates.

Diet	Time for Mastication
12.5kg Forage	16 hours
8kg Forage & 4kg Concentrates	11.5 hours
3kg Forage & 7kg Concentrates	6.1 hours

Table 1: Time required by a 500 kg horse for mastication (Hollands, 2004)

Enamel 'points' develop on the buccal occlusal edge of maxillary CT and the lingual occlusal edge of mandibular CT because of uneven occlusal table wear. This arises from:

- the anisognathic nature of the equine mouth, with mandibular CT being approximately 23% narrower than maxillary CT[16]
- differing CT occlusal table widths
- the direction and force of the equine masticatory cycle (that also differs between the rostral and caudal CT)

Currently, it is advised that routine prophylactic dental procedures should be carried out to remove focal overgrowths and this is usually performed annually or biannually[16]

Dentistry to Improve Feed Digestibility

In horses, Ralston *et al.* (2001) studied the effect of *routine prophylactic dentistry* (removal of focal overgrowths and enamel points) on the digestion of a hay and grain ration as compared with CT that had received a *performance float* (rounding and smoothing of the CT rows, including the occlusal surface)[19] and found that digestibility

of crude protein and fibre was reduced if the occlusal angle of CT 307 was greater than 80 degrees relative to the vertical axis i.e. the CT had been flattened excessively when under-going a *performance float.* Routine correction of small enamel overgrowths did not improve feed digestibility in this study. A further study suggested that dental floating did not result in significant *short-term* changes in body weight, body condition score, feed digestibility, or faecal particle size in healthy pregnant mares.[28]

However, regular floating of sharp enamel points and focal overgrowths can prevent their progression to more serious problems such as oral ulceration, major dental overgrowths, shear-mouth and periodontal disease.[17,21,22] Low body condition score has been linked to presence of dental disease in a study of 300 debilitated working equids (100 horses, 100 donkeys and 100 mules) where 47% of horses, 32% of donkeys and 80% of mules with a body condition score of one or less had significant dental disorders present.[23]

Dietary Influence on Dental Development and Acquired Pathological Conditions

In addition to domesticated diets potentially reducing overall dental wear and promoting the formation of sharp dental overgrowths, diet has been alleged to contribute to more specific dental pathological changes.

Colyer (1906) described periodontal disease as the '**scourge of the horse**,' recording this disease in one third of 484 skulls examined.[25] Baker (1970) recorded an incidence of 60% periodontal disease in horses aged over 15 years[26] and later Wafa (1988) reported an overall incidence of 37% of periodontal disease in an abattoir survey, with 52% of animals showing concurrent periodontial disease when their teeth were erupting.[27] Again the disease was more prevalent in older animals, reaching a peak of 60% in horses over 20 years of age.

Primary equine periodontal disease, however, is uncommon.[28] Dixon found only 7% of referred incisor cases and 4% of referred mandibular and maxillary CT cases to be affected by primary periodontitis.[18,28] The higher incidences described in previous studies is probably due to the inclusion of periodontal disease arising secondarily from other primary dental disorders such as diastemata or displaced teeth.

Hofmeyer (1960) attributed a diet of coarse or chopped food as a predisposing factor to periodontal disease in South African horses.[44] In contrast to most other reports, he stated that the maxillary CT rows were more commonly affected with periodontitis than mandibular CT rows. Feeding of chaff, where small pieces of food can become impacted between teeth, was proposed to initiate gingival damage either mechanically or through bacterial fermentation of these foodstuffs,[25] but little scientific evidence has been presented to support the above claims. Indeed, the feeding of such chopped diets has been advocated as a treatment of CT diastemata.

Caries of cementum, enamel and dentine have been identified in the horse, most frequently in cementum – the latter being both the softest, least mineralised calcified dental tissue, and being the most abundant (with respect to surface area exposure) in the

equine oral cavity.[24] Early studies reported incidences of infundibular caries to be as high as 79-100% in certain ages of equine populations.[30,31] More recently, infundibular caries was reported to occur in 12% of maxillary CT, but not in incisors (0%).[17,18] Infundibular caries appears grossly as a darkly stained region within the infundibular cemental lakes.[32] This dark staining may potentially extend beyond the infundibular cementum into both the enamel and adjacent dentine. The presence of food within equine hypoplastic infundibular cementum can promote infundibular caries which, depending on bacteria present, amount and type of food present, and time, has been proposed as another potential aetiology for apical infection.[24,33,34] The significance of peripheral cemental caries is unknown, however, by weakening and removing occlusal cementum (that contributes considerably to equine CT clinical crown structure),[6] it may both increase the rate of occlusal wear and contribute to the development of diastema and associated periodontal disease. The destruction of peripheral cementum also makes proud areas of brittle enamel on the occlusal surface more prone to fracture. A higher prevalence of peripheral cemental caries has been detected in horses fed a chopped hay and molasses diet and also horse fed an acid treated, low pH silage (Dixon PM 2006, personal communication).

Dentition and the Influence of Diet Selection

There have been no studies to date in horses suggesting that dental health may play a role in diet selection. However, this has become a field in its own right in humans, particularly when considering the elderly where dental health is usually compromised. A strong link has been shown between dietary variety, nutrient intake and dental health. Chewing ability in humans is highly correlated with the number of teeth present.[35] People who cannot chew or bite comfortably are less likely to consume high-fibre foods such as bread, fruit and vegetables thereby reducing their intake of essential nutrients.[36] Guidelines on geriatric equine dentistry often focus on not raising the expectations of the owner to being able to fully cure the dental problems present, and emphasise that attention to dietary modification should be encouraged.[37] The potential for further development of dietary alternatives for the aging equine populations are likely to be an area of future growth.

References

1. Bennett, D. Horse Breeding and Management. Evans J.W. (ed.), pp. 1-37 (Elsevier, Amsterdam,1992).
2. Budiansky, S. The nature of horses: their evolution, intelligence and behaviour. Weidenfield & Nicolson, London (1997).
3. Capper, S.R. The effects of feed types on ingestive behaviour in different horse types. 1-160. 1992. University of Edinburgh.
   Ref Type: Thesis/Dissertation
4. Kirkland, K.D., Baker, G.J., Marretta, S., Eurell, J.A. & Losonsky, J.M. Effects of aging on the endodontic system, reserve crown, and roots of equine mandibular cheek teeth. *Am. J. Vet. Res.* **57**, 31-38 (1996).
5. Kozawa, Y., Mishima, H. & Sakae, T. Evolution of tooth structure in the Equoidea. *J. Nihon Univ Sch Dent.* **30**, 287-296 (1988).

6. Mitchell, S. Peripheral cementum of normal equine cheek teeth: a qualitative and quantitative study. 1-146. 2004. University of Edinburgh. 2004.
Ref Type: Thesis/Dissertation
7. Kilic, S. A light and electron microscopic study of calcified dental tissues in normal horses. 1-193. 1995. University of Edinburgh.
Ref Type: Thesis/Dissertation
8. Leue, G. Handbuch der speziellen pathologischen anatomie der haustiere. J. Dobberstein, G.P.a.H.S. (ed.), pp. 131-132 (Verlag Paul Parey, Berlin,1941).
9. Becker, E. Zahne. Verlag Paul Parey, Berlin (1962).
10. Capper, S.R. The effects of feed types on ingestive behaviour in different horse types. 1-160. 1992. University of Edinburgh.
Ref Type: Thesis/Dissertation
11. Dixon, P.M. Equine Dentistry. Baker G.J.and Easley J. (ed.), pp. 3-28 (W.B. Saunders, London,1999).
12. Lindberg, J.E. & Karlsson, C.P. Effect of partial replacement of oats with sugar beet pulp and maize oil on nutrient utilisation in horses. *Equine Vet. J.* **33**, 585-590 (2001).
13. Myres, J.S. The effects of boby size, grass height and time of day on the foraging behaviour of horses. 56. 1994. Aberystwyth University.
Ref Type: Thesis/Dissertation
14. Taylor, A.C. An investigation of mandibular width and related dental disorders in the equine oral cavity. 2001. Coventry University.
Ref Type: Thesis/Dissertation
15. Tremaine, W.H. Dental care in horses. *In Practice* **19**, 186-199 (1997).
16. Dixon, P.M. *et al.* Survey of the provision of prophylactic dental care for horses in Great Britain and Ireland between 1999 and 2002. *Vet. Rec.* **155**, 693-698 (2004).
17. Dixon, P.M. *et al.* Equine dental disease. Part 3: A long-term study of 400 cases: disorders of wear, traumatic damage and idiopathic fractures, tumours and miscellaneous disorders of the cheek teeth. *Equine Vet. J.* **32**, 9-18 (2000).
18. Dixon, P.M. *et al.* Equine dental disease part 1: a long-term study of 400 cases: disorders of incisor, canine and first premolar teeth. *Equine Vet. J.* **31**, 369-377 (1999).
19. Ralston, S.L., Foster, D.L., Divers, T. & Hintz, H.F. Effect of dental correction on feed digestibility in horses. *Equine Vet. J.* **33**, 390-393 (2001).
20. Carmalt, J.L., Townsend, H.G., Janzen, E.D. & Cymbaluk, N.E. Effect of dental floating on weight gain, body condition score, feed digestibility, and fecal particle size in pregnant mares. *J. Am. Vet. Med. Assoc.* **225**, 1889-1893 (2004).
21. Dacre, I.T. Equine Dentistry. Baker G.J.and Easley J. (ed.) (Elsevier, London, 2004).
22. Scrutchfield, W.L. Equine Dentistry. Baker, G.J. & Easley, J. (eds.), pp. 185-205 (W.B. Saunders Co. Ltd., London, 1999).
23. Roy, C. Dental problems in debilitated equines in Delhi. 267-270. 2002. Hama, Syria. Proceedings of the Fourth International Colloquiem on Working Equines. 4-20-2002.
Ref Type: Conference Proceeding

24. Dacre, I.T. A Pathological, Histological and Ultrastructural Study of Diseased Equine Teeth. 2004. Royal (Dick) School for Veterinary Studies.
Ref Type: Thesis/Dissertation
25. Miles, A.E.W. & Grigson, C. Colyer's Variations and diseases of the teeth of animals. Cambridge University Press, Cambridge (1990).
26. Baker, G.J. Dental disease in horses. *In Practice* 19-26 (1979).
27. Wafa, N.S. A study of dental disease in the horse. 1-205. 1988. National University of Ireland, Faculty of Veterinary Medicine, University College Dublin.
Ref Type: Thesis/Dissertation
28. Dixon, P.M. Equine cheek tooth disease - is periodontal disease still a problem? 1-8. 1992. 4-2-1992.
Ref Type: Conference Proceeding
29. Hofmeyer, C.F.B. Comparitive dental pathology. *J. South African Veterinary Medical Association* **29**, 471-480 (1960).
30. Baker, G.J. Some aspects of equine dental disease. *Equine Vet. J.* **2**, 105-110 (1970).
31. Honma, K., Yamakawa, M., Yamauchi, S. & Hosoya, S. Statistical study on the occurrence of dental caries of domestic animals. *Jap. J. Vet. Res.* **10**, 31-37 (1962).
32. Kilic, S., Dixon, P.M. & Kempson, S.A. A light microscopic and ultrastructural examination of calcified dental tissues on horses: 4. Cement and the amelocemental junction [see comments]. *Equine Vet. J.* **29**, 213-219 (1997).
33. Baker, G.J. Some aspects of equine dental decay. *Equine Vet. J.* **6**, 127-130 (1974).
34. Schumacher, J. & Honnas, C.M. Dental Surgery. *Vet. Clin. North Am. Equine Pract.* **9**, 133-152 (1993).
35. Sheiham, A. & Steele, J. Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people? *Public Health Nutr.* **4**, 797-803 (2001).
36. Brodeur, J.M., Laurin, D., Vallee, R. & Lachapelle, D. Nutrient intake and gastrointestinal disorders related to masticatory performance in the edentulous elderly. *J. Prosthet. Dent.* **70**, 468-473 (1993).
37. Lowder, M.Q. & Mueller, P.O. Dental disease in geriatric horses. *Vet. Clin. North Am. Equine Pract.* **14**, 365-380 (1998).