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DAMAGE BY THE BIT TO THE EQUINE INTERDENTAL SPACE AND SECOND LOWER PREMOLAR

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SUMMARY

Equus caballus mandibles were surveyed in four museum collections. 66 domestic horse mandibles were compared with 12 feral and Przewalski mandibles. Periostitis (bone spur formation) of the interdental space (bars of the mouth) was found in not less than 62% of the domestic hemi-mandibles. Erosion of enamel and dentine was found in 61% of the second lower premolars (Triadan 306 or 406). 88% of the domestic mandibles showed one or both lesions. The more severe the interdental periostitis, the more likely it was that the 06s were eroded. 12 feral and Przewalski mandibles were free of both lesions.

A clinical examination protocol is described for the identification of bit damage in the live horse. By recommending removal of the bit when damage is found, practitioners can test the author's prediction that the bit is a cause of certain idiopathic diseases and many behavioral problems.

INTRODUCTION

Veterinarians have often reported bit damage to the interdental space (e.g., Smith 1993, Tremaine 1998, Jansson et al 1998, Greet 1999, Cook 1999, Johnson 2002, Cook 2002 & 2003, Cook and Strasser 2003). Credit for the first research studies that focused on the interdental space are shared by an archaeologist (Bendrey 2007) and a team of veterinary anatomists (Van Lancker et al. 2007) who surveyed osteological collections. Bendrey found bone spurs on the interdental space in 87.5% of 32 working horses but in none of 28 Przewalski horses. Van Lancker et al found interdental space roughness in 48% of 87 warmbloods or trotters and 25% of 8 donkeys but only 7% of 68 zebra. No lesions were found in 3 Przewalski horses and 3 ponies.

Veterinarians, in general, have been unaware of the damage the bit does to the teeth. The second lower premolars (Triadan 306/406) were first studied by two more archaeologists (Anthony and Brown 1991). They found evidence of bit damage in 60% of 15 hemi-

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mandibles from domestic horses in osteological collections but in none of 31 hemi-mandibles from feral horses. Similarly, Bendrey (2007) reported bevelling of the lower second premolars (306/406) in 43% of 30 worked horses but in only 1 of 22 unworked horses. Exposure of dentine on the rostral edge of 306/406 was present in 22% of 32 worked horses but in none of 28 unworked horses.

This article reports on similar research.

MATERIALS AND METHODS

Population examined

Sixty six mandibles of domestic horses (Equus caballus) were compared with 12 mandibles from feral and Przewalski horses in four natural history museum collections. The examinations were focused on the interdental space (bars of the mouth) and the '06 premolars.

In the domestic group, 27 were male and 39 female. In the feral group (including the zoo-kept Przewalski horses), 4 were male, 7 female and the sex of one was not recorded.

Six of the domestic group were under 5 years old, 12 were 5 -10 years old, 46 were aged and the age of 2 horses was not recorded. Five of the feral group were 5-10 years old and 6 were aged. In the domestic group, 125 hemi-mandibles were eligible for evaluation of the interdental space and 114 for evaluation of Triadan 306 or 406. In the feral group, 24 hemi-mandibles were evaluated for both items.

The provenance of the specimens did not usually include any information about the work that the horse had done during its lifetime. Because of this it was not possible to say, categorically, that every horse had been bitted, though for reasons given later, it seems probable that the great majority were.

Criteria for documenting interdental periostitis

The following scale was used:

Grade 1 (Normal): Interdental space smooth to the touch

Grade 2: Interdental space rough to the touch but exostoses not large enough to show on a survey photograph. Though possibly caused by bit damage, these were counted as normal.[2]

[2] Dental erosion was often present in specimens with grade 1 and 2 interdental periostitis . Clearly, horses can learn to defend themselves from the bit by grasping it between their teeth before serious bone damage occurs.

Grade 3 (Slight): Exostoses less than 2mm in height (Fig.2) but large enough to be recorded photographically

Grade 4 (Moderate): Exostoses 2-4mm in height or width.

Grade 5 (Severe): Exostoses 4mm or greater in height or width (Fig.3) or a loss of bone from sequestrum formation

Criteria for documenting dental erosion

The lower second premolars (306/406) are the first to be damaged by the bit, so the frequency of erosion was based on these. The entire molar arcades, canines and incisors were also examined.

Bit erosion of 306/406 included a cascade of changes which usually started on the occlusal surface but sometimes on the rostral edge of the tooth (Fig.1). One or more of the following changes were found. A common sequence started with:

1. Loss of the enamel ridges and a smoothing of the occlusal surface from mesial to caudal. When the enamel folds no longer stand proud of the surrounding dentine, this is referred to below as loss of the 'Braille' effect.

2. A concurrent bevelling of the 90^0 angle between occlusal surface and rostral edge

3. Erosion of enamel and dentine on the rostral edge, blunting the normal ship-like prow of the tooth. This commences at the top of the tooth and spreads downwards, creating a buttress conformation in the uneroded lower section.

The above three lesions occurring on Triadan 306/406 were considered pathognomic and specific for bit erosion. The only caveat to this statement relates to bevelling and the need to differentiate bit wear from iatrogenic 'bit-seating' (see 'Discussion').

Less frequent and non-specific findings included;

4. Chip fractures on the rostral edge just above the gum, partial or total loss of the functional crown, diastema formation at '06/'07, periodontal disease, and osteoporosis of alveolar bone.

5. Finally, the roots of 306 or 406 were sometimes shed, followed by either healthy closure of the empty alveolus, a local osteitis, or an osteomyelitis of the entire interdental ramus.

In no case were lesions in category 4 & 5 used to document a positive diagnosis of 'eroded 306/406' in Table II. These lesions were always supplementary to lesions in category 1 to 3 and did not occur in isolation.

A cascade of similar changes sometimes affected 307/407 and even 308/408. A progressive mesial-to-caudal smoothness of the occlusal surface of 106/206 was seen occasionally, often accompanied by loss of infundibular cement.

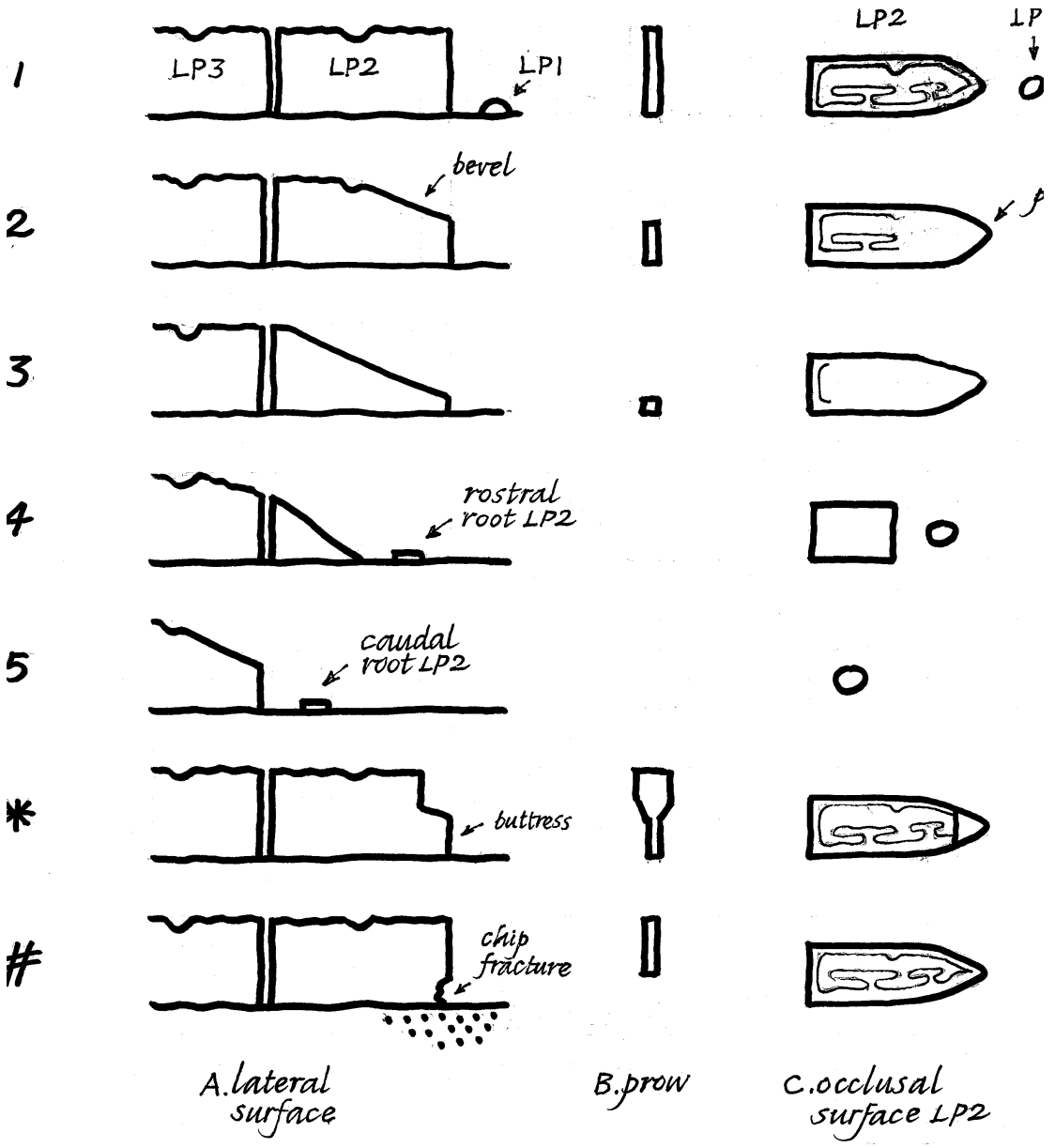

Fig.1. Diagrammatic representation of various features of bit-induced dental damage

Key: LP1 = first lower premolar (405); LP2 = second lower premolar (406); LP3 = third lower premolar (407) Prow = rostral edge

1 - Normal anatomy of 406, showing the location of 405 (wolf tooth) when present. On the occlusal surface, the linear pattern represents the enamel folds standing proud of the surrounding dentine and cement to produce the essential grinding mechanism (the 'Braille' effect).

2-5 = Progressive stages of dental erosion caused by the rider drawing the bit between the teeth and the horse holding or chewing the bit.

2 = Erosion of the mesial half of 406, producing a marked bevel, reducing the height of the rostral edge and partially eliminating the 'Braille effect'

3 = With further erosion the rostral edge of 406 is reduced to a minimal height and the occlusal surface is almost entirely smooth

4 = Continued erosion results in the mesial half of 406 being rubbed down to its root and a bevel developing on 407

5 = The final stage of 406 erosion and shedding of the tooth, with only the caudal root remaining.

** = Erosion of the rostral edge of 406 as a result of repeated bit damage. This produces a buttress effect on the lower section of the rostral edge, as seen on a lateral view and a blunting of the upper section, as seen on a frontal view. The primary dentine will have been exposed on the upper section and, with advanced erosion, secondary dentine may also be exposed.*

 # = a bit-induced chip fracture of 406 at the base of its rostral edge, accompanied by osteoporotic changes in alveolar bone.

Summary of criteria for bit damage

One or more of the following lesions:

- Grade 3-5 interdental periostitis
- Sequestration of the interdental spine
- Macroscopic erosion of enamel and dentine on 06s[3]

RESULTS

Domestic Group

Interdental periostitis (grade 3-5) was found in 78 (62%) of 125 domestic hemi-mandibles (Table I). Four of the grade 5 specimens had sloughed sequestra

[3] Erosion of cement occurs with normal dietary wear and was discounted

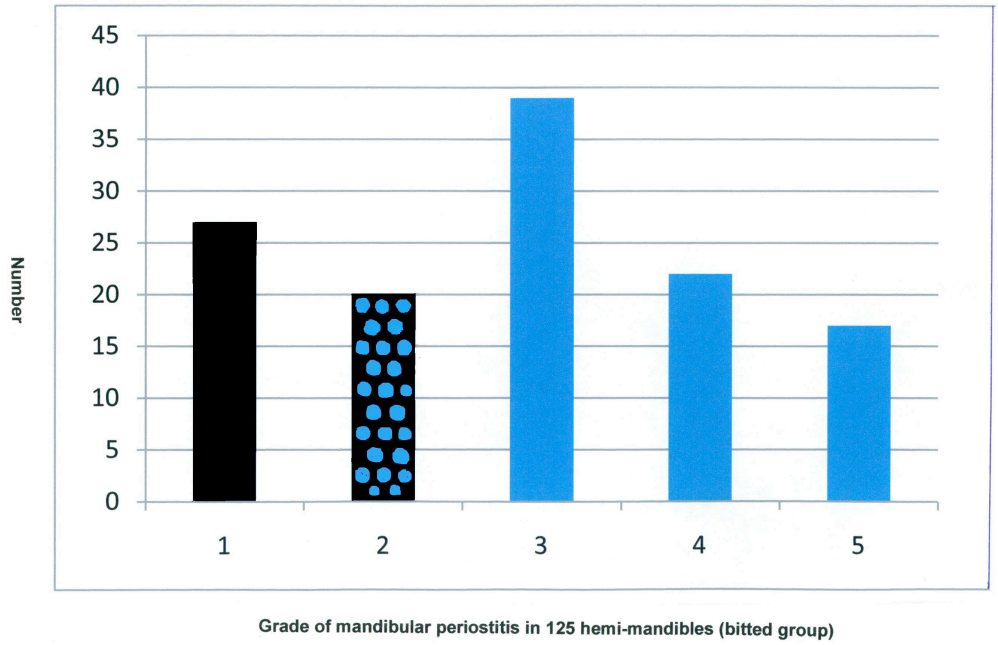

Table I: Histogram of interdental periostitis grading for the domestic group (125 hemi-mandibles)

Key: black = normal; blue = bone spurs; polka dot blue = indicates that a grade 2 may represent the early stages of periostitis but the specimen has been given the benefit of the doubt and counted as normal.

[Errata: The horizontal axis should read 'Grade of periostitis in 125 mandibles (domestic group)']

If a finger is run backwards and forwards over the interdental spine of a normal macerated mandible, the spine feels smooth. New bone growth (periostitis) resulted in roughness, gross bone spurs or a wave formation. If a section of bone had died and a sequestrum been shed, the interdental spine showed a concave, 'scooped- out' section.

Macroscopic erosion of enamel and dentine was found in 69 (61%) of 114 second lower premolars.

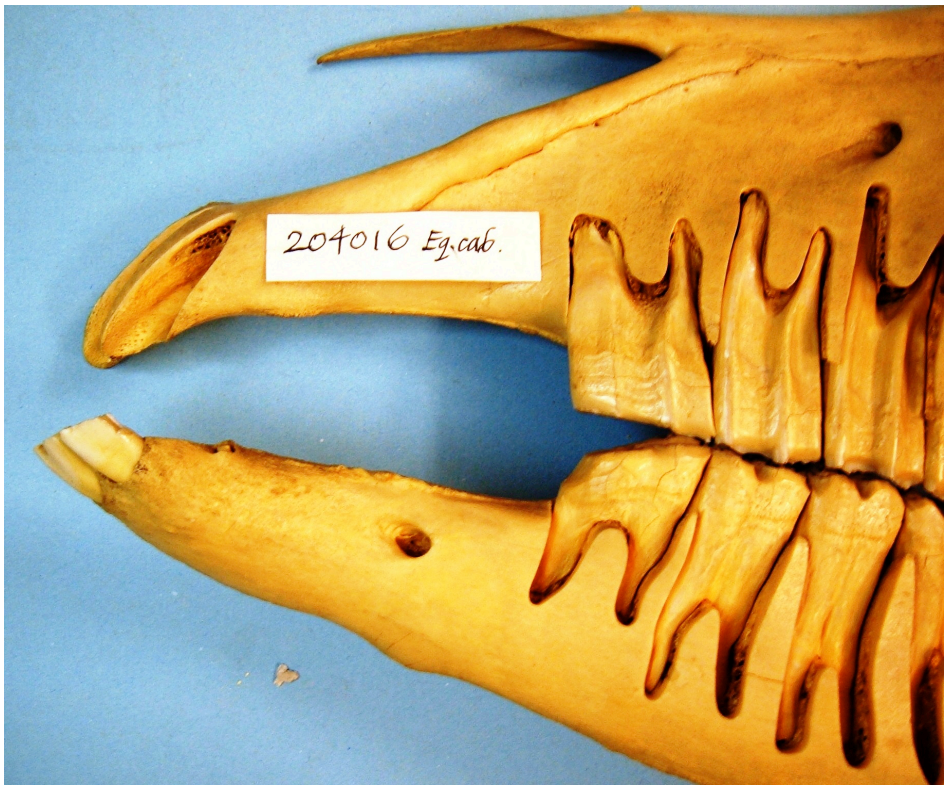

Fig 2. Beveling of 306 occlusal surface together with erosion and blunting of the surviving portion of the rostral edge. Grade 3 interdental periostitis.

Fig. 3. Bilateral grade 5 interdental periostitis and erosion of the mesial half of 306/406 occlusal surfaces.

58 (88%) of 66 mandibles showed evidence of either interdental or dental damage (Table II).

As the grade of interdental periostitis progressed from 1-5, the percentage frequency of accompanying dental erosion also increased. In sequence, the percentages were 44, 58, 64, 67, and 80%.[4]

	Number of Hemi-mandibles evaluated	**EVALUATION**	**# of Hemi-mandibles (left & right)**
A. Interdental space	125	Grade 1 or 2 (normal)	47(38%)
		Grade 3 to 5 (abnormal)	78 (62%)
B. Triadan 306/406	114	NAD	45 (39%)
		Eroded	69 (61%)
	Number of mandibles evaluated		
SUMMARY	66	NAD (neither A nor B)	8 (12%)
		Bit damage (A or B)	58 (88%)

Table II: Tabulation of bit damage in the domestic group

Key: NAD - no abnormality detected

Feral Group

No interdental periostitis or dental erosion was found in any of the 12 skulls. In general, they showed excellent oral health. One Przewalski had a wave mouth.

DISCUSSION

Comparison of results

The control population in this study was small (n12) but the normality of its oral health corresponded well with previous workers' results from larger numbers of feral and Przewalski horses, and zebra.

[4] Note that 44% of the hemi-mandibles with grade 1 interdental periostitis (i.e. a normal interdental space) showed dental erosion

The percentage of interdental periostitis in the domestic group (62%) compares with Van Lanker's 48% and Bendrey's 87.5%. The percentage of dental erosion (61%) compares with Anthony's 60% and Bendrey's 59% erosion of the rostral edge and 43% beveling.

Interpretation of results

a) Alternative hypothesis for interdental periostitis.

Van Lancker et al. proposed that interdental periostitis might be caused by either an extrinsic factor (the bit) or an intrinsic factor (tension from the buccinator muscle at its origin on the interdental spine). They conceded that the bit might still be responsible for abnormal tension in the buccinator muscle because of the bit's action as a lip retractor.[5]

The present author adds a further reason why the buccinator muscle may be stressed by the bit. A jointed snaffle and a curb bit both exert a nut-cracker action on the side of the horizontal ramus, immediately below the interdental spine. Both bits would traumatize the buccinator muscle at its origin from the spine.[6]

Dental erosion data would have helped Van Lancker et al to differentiate between extrinsic and intrinsic factors but they did not examine the teeth. In the present study, the step-wise increase in the frequency of dental erosion with the grade of interdental periostitis favors the idea that the bit causes both lesions.

Van Lanker et al's feral equids had "a very low prevalence of bone irregularities of the interdental space." It remains to be explained why 5 of their 68 zebra (7%) showed irregularities. Van Lancker suggested, "an altered way of grazing and feeding, e.g., caused by dental malocclusions or malformations."

Bone spurs most frequently developed on the interdental spine immediately dorsal to the mental foramen. As this is also the region on which the bit most frequently lies, the distribution further supports the extrinsic hypothesis for the cause of interdental periostitis. If the buccinator muscle was the primary cause, one would expect exostoses to be spread along the whole of the interdental spine.

b)

The absence of any provenance for most of the specimens meant that it was not possible to state categorically that every specimen came from a bitted horse.

[5] Lip tissue is highly elastic. When strong traction on the reins is applied, the bit draws the angle of the lip to a position level with the 06s or 07s. At this point, the bit is grabbed between the premolars. The horse does not so much 'get the bit between his teeth' as the rider places it there. This feature, a gaping mouth and the horse's ability to further retract the bit with its tongue, explains why the bit can occasionally erode the occlusal surface of the 08s.

[6] The anatomy of the region renders it likely that both bits also press, bilaterally, on the sensory nerve and trap it against bone just rostral to the mental foramen.

Nevertheless, the lesions found provide strong circumstantial evidence that the majority were bitted. lesions mandibles that pathognomic

c) Time interval between last bitted use and death.

If the interval was several years, as for example when young horses are retired to stud, evidence of erosion in hypsodontic teeth might be eradicated by their further eruption and the resumption of normal patterns of wear. In time, bone spurs on the mandible might also be eliminated by remodeling. This would lead to an underestimate of the frequency of bit damage in the collection. The preponderance of females in the domestic group suggests that some were brood mares. The eight normal specimens from the domestic group (comprising 7 females and 1 male) were all from aged horses. These included one brood mare that died at 39 after giving birth to her 20th foal.

d) Age at death

Horses that have been bitted regularly for many years will be more likely to exhibit evidence of bit damage than young horses.

e) Incomplete specimens

As bit damage first appears in the mandible, absence of the upper jaw in 6 skulls did not prevent the specimen from being included in the survey. It was still possible to determine that 306/406 erosion was caused specifically by the bit and not by, say, wear from an overgrown 106/206. Similarly, a smooth or partially smooth occlusal surface on 306/406, 307/407, or even 308/408, with nothing comparable on 309/409 seems most probably to have been caused by a bit and could not, for example, be attributed to geriatric smooth mouth. Again, occlusal wear of 306/406 from an opposing 106/206 would have retained the 'Braille' effect. Finally, pathognomic exposure of dentine on the rostral edge of the 06s could not have been caused by brachgnathia or 106/206 defects.

f) Iatrogenic changes

Beveling of the ‘06’s by the bit must be differentiated from the practice of ‘bit-seating.’ The beveling seen was often accompanied by blunting of the rostral edge and buttress formation. These latter changes could not have been caused by ‘bit-seating.’ Similarly, when the degree of bevelling was advanced, as it was in many specimens (even to the point of involving 307/407), this could not have been caused by ‘bit-seating’ at a time when only hand tools were used. As beveling was commonly accompanied by interdental periostitis it was more likely that the bit caused both lesions. Finally, the specimens were mostly collected in the 19th century, when ‘bit-seating’ was probably less common.

g) Possible extrapolation weakness

It might be suggested that the high frequency of bit damage, as judged by a museum collection, may not be a reliable predictor for the present day. For example, the specimens examined might have included a higher proportion of driving horses than today's population. Sadly, this comforting thought is refuted by the author's experience that the bit is an all too common cause of behavioural problems and certain idiopathic diseases in today's horses

Diagnosis of bit damage in the live horse

The author predicts that bit damage in today's horses is common. With awareness of the nature of the lesions found in museum specimens, practitioners can now test this prediction.

Unless a mouth gag is already being used for a total oral examination, the more limited examination required for this particular purpose needs no gag. Sedation to reduce tongue, jaw, and head movement will increase the accuracy of findings. In normality, the interdental spines should be bilaterally symmetrical and each spine should be flat, hard and 'clean-edged.' Abnormalities include asymmetry, softness and convexities.

A two-step protocol is recommended:

1. Digital palpation: Standing on the left side of the horse's neck, facing front, insert your index fingers into the mouth and palpate both interdental spines simultaneously, in order to compare them. Palpate the rostral edge of both '06s for symmetry, angle, height and width.

2. Visual and digital inspection: Wearing a headlamp, stand in front of the horse, grasp the apex of the tongue with one hand and use your closed fist, with thumb on top, as a mouth gag. With the fingers of the other hand resting on the 'D' of the head collar, use your thumb to retract the angle of the lip. Look at the interdental space and '06. Subsequently, use your thumb to palpate the occlusal surface of '06, checking that it is level and rough, not sloping and smooth. Double check the rostral edge. Switch sides and repeat.

Interdental periostitis is likely to be under-estimated by an oral examination. A grade 2 periostitis is not being counted as abnormal and a grade 3 periostitis may not always create a palpable lesion. Nevertheless, accompanying evidence of dental erosion may be present in both cases and is easier to detect.[7]

Cause and effect can be correlated if the bit is removed and behavioural problems disappear in the following weeks. Many problems disappear in the first four minutes of day one (Cook and Mills 2009).

Because of its relevance to safety, welfare and performance, an assessment of bit damage would be a useful addition to a purchase examination.

[7] Dental erosion was often seen in the museum specimens, even when the interdental space was 'normal' (grade 1 or 2).

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REFERENCES

Anthony, D. W and Brown, D. R. (1991): The origins of horseback riding. *Antiquity*, 65, 22-38
Bendrey, R. (2007): New methods for the identification of evidence for bitting on horse remains from archaeological sites. *Journal of Archaeological Science,* **34**, 1036-1050
Cook, W. R. (1999): Pathophysiology of bit control in the horse. J *Equine Vet Sci,* **19**, 196-204
Cook, W. R. (2002): Bit-induced asphyxia in the horse: Elevation and dorsal displacement of the soft palate. *J Equine Vet Sci*, **22**, 7-14
Cook, W.R. (2003): Bit-induced pain: a cause of fear, flight, fight and facial neuralgia in the horse. *Pferdeheilkunde* **19**, 75-82
.
Cook, W.R. and Mills, D.S. (2009): Preliminary study of jointed snaffle vs. crossunder bitless bridles: Quantified comparison of behaviour in four horses.
Equine vet. J. **41** (1) 827-830 doi: 10.2746/042516409X472150
Cook, W. R. and Strasser, H (2003): *Metal in the mouth: The abusive effects of bitted bridles.* Sabine Kells, Qualicum Beach, BC, Canada
Greet, T. R. C (1999): Oral and dental trauma in *Equine Dentistry* 1st edition. Eds., G. J. Baker, and J. Easley. W. B. Saunders, London pp 60-69
Jansson, N, Hesselholt, M, and Falmer-Hansen, F (1998): Extirpation of a mandibular canine tooth in a horse as a treatment for severe bit-induced trauma to the bar. *Equine vet edu* **10**, 143-145
Johnson, T.J. (2002): Surgical removal of Mandibular Periostitis Bone Spurs Caused by Bit Damage. *Proceedings* American Association of Equine Practitioners, **48**, 458-462
Smith, J.C. (1993): Osteitis and sequestrum formation of the interdental region in 11 polo ponies. V*et Rec.* **133**, 188-189
Tremaine, W.H. (1998): Management of equine interdental injuries. *Equine vet edu.* **10**,146-154
Van Lancker, S. Van Den Broeck, W and Simoens, P (2007): Incidence and morphology of bone irregularities of the equine interdental space (bars of the mouth) *Equine vet edu,* **19** (2) 103-106

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CONFLICT OF INTEREST
The survey's results point to an indictment of the bit as a method of communication. For the last ten years, the author has been the Chairman and CEO of a company that markets an alternative to the bit and so declares a conflict of interest. The author owns a patent on a bitless bridle.