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Special Article

A study of open-mouthed oblique radiographic projections for evaluating lesions of the erupted (clinical) crown

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Introduction

The equine head provides excellent contrast between calcified tissues and air, which makes radiography rewarding diagnostically. There have been recent advances in the popularity of alternative imaging techniques for the equine head, such as nuclear scintigraphy (Weller *et al*. 2001), computerised tomography (CT) (Tietje *et al*. 1996) and magnetic resonance imaging (MRI) (Tucker and Farrell 2001). However, the necessity for expensive and sophisticated equipment for these techniques, and of general anaesthesia of patients for CT and MRI, means that radiography is likely to remain the most frequently used imaging modality for the foreseeable future, especially in general practice, because even low-power portable x-ray units can be used effectively for dental radiography.

Conventional (closed-mouthed) radiographic projections of the equine maxillary cheek teeth include standing lateral, 30° dorsolateral-lateral oblique and dorsoventral views. Similarly, mandibular cheek teeth are traditionally radiographed using standing lateral and 35–45º ventrolateral-lateral oblique views (Wyn-Jones 1985; Lane *et al*. 1987; Gibbs 2000). In the majority of cases, these views adequately image the reserve crowns, dental apices, *lamina dura denta* and alveolar bone, as well as the associated mandible, maxilla and sinonasal structures. While the above oblique projections separate the left and right cheek teeth rows, giving greater detail of the reserve crown, apices and supporting bones, most or all of the erupted (clinical) crown is obscured in these projections by superimposition of the erupted crowns of the opposing cheek teeth row, in all but very aged horses with short reserve crowns.

To date, most emphasis in equine dentistry has been placed on disorders of the apices and reserve crowns but, increasingly, diseases of the erupted crown are being recognised (Dixon *et al*. 1999; Baker 2000). These are areas which are difficult to examine reliably in the horse, especially if the caudal cheek teeth are affected, even with the use of a full-mouth gag (speculum) and instruments such as buccal and lingual retractors, dental picks and flexible endoscopes. Therefore, ancillary diagnostic techniques, such as radiography, provide an alternative for accurate assessment of the clinical crowns of cheek teeth. **The purpose of this study was to describe the use of 2 additional radiographic views, the open-mouthed dorsolateral-lateral oblique and the open-mouthed ventrolateral-lateral oblique, to evaluate the erupted crowns of the mandibular and maxillary equine cheek teeth, respectively (Fig 1); and to investigate the oblique angle, which would facilitate obtaining the optimal radiographic view of the clinical crowns.** Although the use of open-mouthed oblique (OMO) views has been mentioned briefly in the literature (Dixon *et al*. 1999; Gibbs 2000), there appears to be no documented description of this technique, nor details of the optimal angle for obtaining these views of the equine skull.

Examples of the use of these techniques in 5 clinical cases are also presented and show that they are a valuable ancillary diagnostic aid for imaging diastemata and other disorders affecting the erupted crown of the maxillary and mandibular cheek teeth.

Materials and methods

A Siemens Gigantos 1012MP x-ray unit, with a 35 x 43 cm, medium speed, rare earth cassette (DuPont, Ultra-Vision Fast Detail) and medium speed film (CEA, RP) combination, and a film focal distance of 100 cm, were used to obtain all radiographs.

Cadaver skulls

Evaluation of the optimal angle for imaging the clinical crowns was conducted using 5 equine cadaver skulls (3 horses, 2 ponies). The age of the skull was estimated from the degree of incisor eruption and wear, and the length of reserve crown of the cheek teeth. Two skulls were judged to be 5 years of age, 1 approximately age 10 years, and 2 judged to be age 10 and 15 years, respectively. A 10 cm length of 7 cm diameter PVC tubing was placed between the incisors,

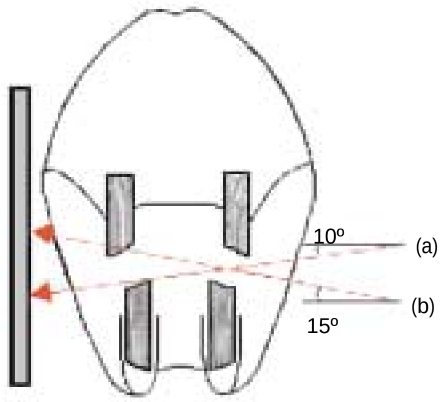

***Fig 1:** Diagram of transverse cross-section through head at the level of cheek teeth, showing beam direction (arrows) and cassette position for open-mouthed oblique (OMO) projections of a) 10° dorsolateral-lateral oblique and b) 15° ventrolateral-lateral oblique.*

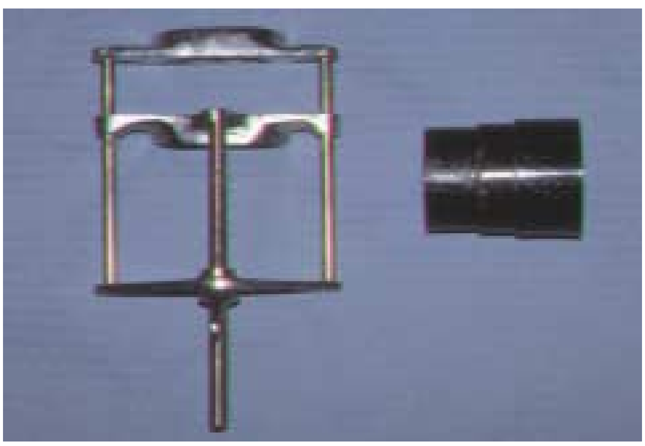

***Fig 2:** Butler's gag (left) and hollow PVC tubing (right). Either can be placed between the incisors to separate the maxillary and mandibular cheek teeth arcades.*

and the x-ray cassette positioned on the right side of the skull in a vertical plane, as close as possible and parallel to the long axis of the head. The right side of each skull was radiographed using open-mouthed 5°, 10°, 15° and 20° dorsolateral-lateral oblique views, and 5°, 10°, 15° and 20° ventrolateral-lateral oblique views, centred at the level of the occlusal surfaces of the cheek teeth, at the rostral extremity of the facial crest. The primary beam was directed exactly perpendicular to the long axis of the head in the rostro-caudal plane. Standard (closed-mouthed) 30° dorsolateral-lateral and 35° ventrolateral-lateral views of the cheek teeth were also taken of each skull.

The images of each skull were randomised and assessed blindly by 4 clinicians with extensive experience of reading equine skull radiographs. Clinicians were asked to select the 2 radiographs for each skull which most clearly imaged the entire length of erupted crowns of the mandibular and maxillary cheek teeth arcades.

Agreement between the 4 clinicians was evaluated using the Friedman repeated measures test for nonparametric data, to assess the amount of interclinician variation for each set of

***Fig 3:** A sedated horse with gag, rope headcollar and nose twitch in place, being radiographed using an OMO projection for the mandibular cheek teeth.*

maxillary and mandibular OMO radiographs. The same statistical test was used to detect interskull variation between the 5 maxillae, and the 5 mandibula. Finally, the median angles chosen for optimal maxillary and mandibular OMO radiographs were compared using the Mann-Whitney test to evaluate if there was a significant difference in this angle between the 2 cheek teeth rows.

Clinical cases

The OMO radiographic technique was used in 5 clinical cases which were referred to the hospital with signs of dental disease and where oral examination indicated that abnormalities of the erupted crown existed. These 5 horses were median age 6 years (range 3–13 years), 2 Warmbloods, 1 Thoroughbred and 2 ponies. Sedation of the horses was necessary both to obtain skull radiographs safely and to facilitate separation of the maxillae and hemimandibles, and was achieved by administration of romifidine (0.03–0.05 mg/kg bwt i.v.) with butorphanol (0.01 mg/kg bwt i.v.). In these cases, separation of the maxillae and hemimandibles was achieved by using a Butler's gag (speculum) or a 7 cm diameter section of PVC pipe (**Fig 2**), which was readily placed between the incisors in the sedated horse (**Fig 3**) and enabled the tongue to be held in the normal midline position. A radiolucent rope or canvas halter with a long lead was used to provide manual restraint of the patient during radiography. To achieve accurate collimation, the light-beam diaphragm was rotated so that alignment of the x-ray beam conformed to the angle of the head. A cassette holder was used to avoid exposure of personnel to the primary beam, and suitable radiation protection (gloves, aprons, thyroid guards) were utilised by handlers.

OMO radiographs of the affected cheek teeth row(s) were taken at 15º ventrolateral-lateral for the maxillary cheek teeth and 10º dorsolateral-lateral for the mandibular cheek teeth, using the radiographic technique described for cadaver skulls. Standard closed mouth radiographic views of the affected cheek teeth row(s) were also taken in all cases.

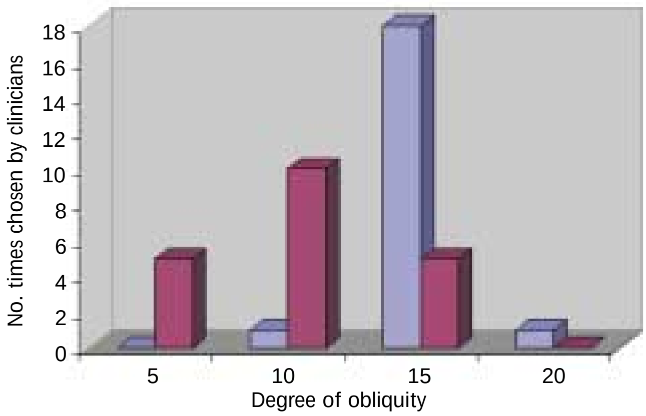

Fig 4: Frequency that OMO radiographic views were chosen by examiners. ■ = Maxillary CT; ■ = mandibular CT.

Results

Cadaver skulls

Figure 4 illustrates the distribution of choices made by clinicians when viewing the maxillary and mandibular OMO radiographs. The median angle chosen as optimal for assessing maxillary cheek teeth was found to be 15º (chosen on 90% of occasions) and for mandibular cheek teeth 10º (chosen on 50% of occasions). The Friedman test showed that there was no significant difference between the 4 clinicians when assessing each individual maxilla and mandible ($P = 0.367$, $Fr = 4.0$). There was no significant difference between the 5 skulls when clinicians chose the optimal angle for viewing erupted crowns of the maxillary cheek teeth ($P = 0.287$, $Fr = 5.00$). However, there was significant interskull variation when clinicians chose the optimal angle for viewing the mandibular cheek teeth ($P = 0.007$, $Fr = 14.18$). Finally, there was a significant difference between the angles chosen for maxillae as compared to mandibles when median angles were compared using the Mann Whitney test ($P<0.01$).

In 2 skulls, where the curve of Spee (natural dorsal curvature of the occlusal surface of the caudal 3 cheek teeth) was marked, clinicians noted that a single oblique view did not allow optimal assessment of both the rostral and caudal mandibular cheek teeth. It appeared in these cases that 2 dorsolateral-lateral views differing in angle by 5º were necessary to assess all of the caudal and rostral cheek teeth optimally. A more horizontal view (i.e. 5º or 10º dorsolateral-lateral) imaged the caudal teeth more accurately by preventing superimposition of the opposing arcade, whereas a view which was 5º more vertically orientated (i.e. 10º or 15º dorsolateral-lateral) preferentially imaged the rostral teeth, because a larger portion of the erupted crown was visible.

Factors which were judged subjectively to influence the optimal oblique angle for OMO projections in this study included absolute size of skull, length of erupted crown, presence of abnormalities of wear and degree of angulation of the curve of Spee.

If the primary beam was not exactly perpendicular to the long axis of the head in the rostro-caudal plane, distortion and artefactual overlapping of the individual cheek teeth crowns resulted, which prevented accurate evaluation of the interdental regions. Divergence of x-rays from the centre of the beam causes a degree of artefactual narrowing of diastemata at the rostral and caudal extremes of the cheek teeth row. However, in a Thoroughbred-sized horse where the cheek teeth row length is *circa* 18 cm, divergence affects only 6–7 cm of the row rostrally and caudally from the centre of the beam. Due to the very short distances involved, the effect of such beam divergence is minimal and, therefore, not diagnostically significant. A similarity can be drawn between assessment of diastemata in the horse and assessment of intervertebral disc spaces in the spinal column of small animals, where clinicians routinely evaluate disc spaces within a distance of 12–14 cm, without requiring several views centred at different points (Smallwood and Spaulding 1998). Comparison of standard closed mouth and OMO radiographs showed that standard closed mouth radiographic projections did not allow better evaluation of the erupted crown than open-mouthed views in any skull.

TABLE 1: Clinical signs shown and radiographic findings

Case No.	Clinical signs	Radiographic findings
1	Quidding	a) Initial examination: Bilateral mandibular diastemata, multiple sites (**Fig 5**). b) 10 months later: reduction in size of diastema between 308/309 (**Fig 6**).
2	Weight loss	Bilateral mandibular diastemata, multiple sites. Retained dental caps 107, 108, 308 (**Fig 7**).
3	Quidding	Coronal fracture of 309 and caudal aspect of 308. Corresponding overgrowth 209.
4	Quidding	Coronal fracture of rostral 208, corresponding overgrowth 308. Diastema between 209/210. Wavemouth all cheek teeth rows.
5	Facial swelling, unilateral nasal discharge	Standard radiographic views: oligodontia, periapical infection of 106. OMO view: oligodontia. Bilateral mandibular diastemata, multiple sites, caudal dental overgrowths 310, 410 (**Fig 9**).

Clinical cases

Clinical signs shown and radiographic findings are detailed in **Table 1**. Radiographs of the 5 clinical cases are presented in **Figures 5–10**. Radiographic examination of the erupted crowns was most useful for detection of diastemata (**Figs 5, 6, 7, 9, 10**), which were impossible to evaluate on standard oblique views. Fractures of the erupted crown were seen in 2 cases (**Figs 8, 9**), abnormalities of wear such as exaggerated transverse ridges, wave or step mouths in 4 cases (**Figs 6, 8–10**), and the presence of retained deciduous cheek teeth remnants ('caps') in 1 case (**Fig 7**). All abnormalities of the erupted crown were visualised more clearly on OMO views than on standard oblique views.

Fig 5: 10° dorsolateral-lateral OMO radiograph of a 4-year-old Warmblood gelding showing a large diastema present between 308 and 309. Additionally, a smaller diastema is present between 307 and 308.

Fig 6: Further radiographs of the horse in Figure 4, taken 10 months later. Note *that this radiograph was not taken at the optimal angle for evaluation of the mandibular cheek teeth. There is some reduction in size of the widest diastema. This is due to continued eruption of the angulated rostral and caudal cheek teeth in a young animal, causing subsequent compression of the occlusal surface of the mandibular cheek teeth row.* ***Note*** *enlargement of the focal overgrowths on 208 opposite the previously largest diastema.*

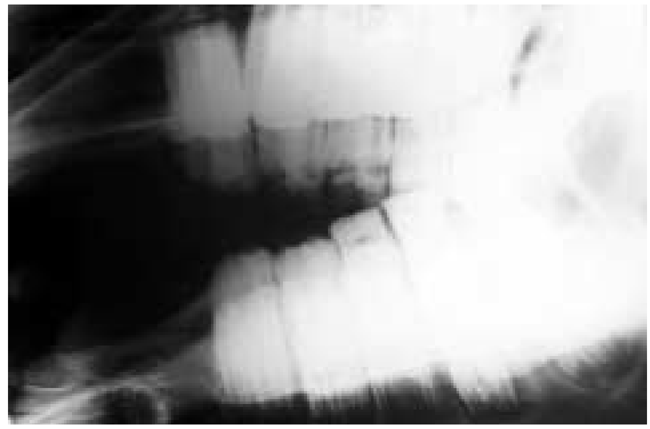

Fig 7: 10° dorsolateral-lateral OMO radiograph of a 3-year-old Warmblood gelding. *Diastemata are present between 308 and 309, and 309 and 310.* ***Note also*** *the presence of deciduous cheek teeth remnants ('dental caps') on 308, 107 and 108.*

Fig 8: 10° dorsolateral-lateral OMO radiograph of a 6-year-old Thoroughbred gelding. *Fractured remnants of 309 are present both rostrally and caudally at the coronal aspect. A lay equine dental technician had attempted unsuccessfully to remove this tooth on 3 occasions.* ***Note also*** *the iatrogenic fracture of the caudal aspect of 308 and the mild 'stepmouth' involving 209 in the opposing maxillary cheek teeth row.*

Discussion

Open-mouthed oblique (OMO) radiographic projections separated the mandibular and maxillary arcades and used a lower angle of incidence of the x-ray beam to the horizontal (10–15º) compared to standard oblique projections (30–45º), thereby avoiding superimposition of the opposing cheek teeth over the area of interest. The direction of the x-ray beam was the opposite to that utilised to obtain standard oblique views of the cheek teeth; i.e. to image the maxillary cheek teeth apices, a dorsolateral-lateral projection was used, whereas to image the erupted crowns a ventrolateral-lateral projection was utilised. These OMO projections allowed for better radiographic views of the erupted crown and hence more accurate diagnosis of lesions affecting this area, in some cases clearly highlighting lesions which were not visible on standard, closed mouth oblique projections.

There was no significant difference between the 4 clinicians' choice of radiographic projection that best imaged the erupted crowns of each individual maxilla and mandible, and this provides increased evidence of the validity of their findings (Martin and Bonnet 1987). The optimal angle for imaging the erupted crowns varied between individual skulls, but more so for the hemimandibles than the maxillae (interquartile range = 15.0–15.0 for maxillae and 6.25–13.75 for hemimandibles). Lane *et al*. (1987) also noted the need for variation in angle of obliquity (for standard oblique radiographic projections of the mandibular cheek teeth) to compensate for varying width of head and intermandibular distance. They found that a more horizontal beam was required for broad heads and a more vertically directed beam for narrow heads. Gibbs (2000) commented that an angle of up to 45º from the horizontal is required for narrow heads where the dental arcades are closer together.

Fig 9: 15° ventrolateral-lateral OMO radiograph of a 13-year-old gelding. *Tooth 208 is fractured with loss of its rostral portion. A large overgrowth on the corresponding mandibular cheek tooth (308) has developed. Additionally, a diastema is present between 209 and 210.* ***Note*** *the presence of 'wavemouth' affecting all 4 cheek teeth rows. Teeth 306 and 406 are prominent (tall), with 106 and 206 correspondingly short, a puzzling feature of many normal horses.*

Fig 10: 10º dorsolateral-lateral OMO radiograph of a 9-year-old pony mare with oligodontia (only 5 cheek per row). *Diastema are present between 306 and 307 and 307 and 308. There are corresponding protruding transverse ridges on 207 and 208, and a large caudal hook on 310.*

The degree of separation of the cheek teeth caused by placing the PVC tube between the incisors should be inversely related to the absolute size of the skull, i.e. a 7 cm diameter separation of the incisors of a small pony would cause proportionately more separation of the cheek teeth than in a Shire. Due to wear, the total crown length decreases constantly following eruption; however, it is not known if the length of erupted crown varies with age. Disorders such as wavemouth and shearmouth influence the length of erupted crown and hence dictate the angle at which the erupted crowns can be optimally imaged. Additionally, there is much individual variation in how wide horses can open their mouths without showing resentment of the gag. This factor is also influenced by the level of sedation.

In the 2 skulls which had pronounced curves of Spee, 2 radiographic views differing by 5° were required in order to image optimally the erupted crowns of both the rostral and caudal mandibular cheek teeth. This phenomenon partially explains the significant difference found between skulls when choosing the optimal angle for viewing the mandibular cheek teeth, whereas no significant interskull variation was seen in the maxillary arcades.

Diseases of the equine clinical crown are being recognised with increasing frequency (Dixon *et al*. 1999). These include diastemata, traumatic or idiopathic fractures of the erupted crown, abnormalities of wear such as exaggerated transverse ridges, wave- or stepmouths, supernumerary or reduced numbers of cheek teeth (polydontia, hypodontia) and the presence of retained and impacted deciduous cheek teeth remnants.

Dixon *et al*. (1999) reported that diastemata (the presence of a detectable interdental space between the cheek teeth), was diagnosed as the primary dental problem in 16 of 400 referred dental cases. Diastemata can occur in young horses due to insufficient angulation of the rostral and caudal cheek teeth, or when the tooth buds develop too far apart (Dixon *et al*. 1999). It can also occur concurrently with other disorders, such as dental displacements. Equine cheek teeth narrow towards their apices and, in older horses, the decreased rostro-caudal length of the erupted crown can result in diastemata, often in multiple sites. Dental loss may cause clinically significant diastemata, if drifting of the remaining teeth towards the defect occurs. Horses with diastemata may suffer from food impaction in the interdental spaces, which may lead to progressive periodontal food pocketing causing gingivitis, periodontitis and significant oral pain (Dixon *et al*. 1999; Easley 2000).

Diastemata are underdiagnosed in equine practice, due to the difficulty of reliable clinical examination of the erupted crowns, especially of the caudal cheek teeth (Dixon *et al*. 1999). Even with the use of full mouth gags, rigid and flexible endoscopes, high powered light sources and buccal and lingual retractors, visual examination of the affected occlusal area is often unsatisfactory. Careful palpation of the gingival margins adjacent to any diastemata can reveal impacted food with a foetid smell. However, radiography of the affected area can be of invaluable assistance in providing a definitive diagnosis of the severity and extent of the condition. This assessment is important to plan optimal treatment and allow for a more accurate prognosis to be given. For example, if a single diastema is found to be the cause of severe periodontal pain, extraction of a single tooth on one side of the diastema may resolve the disorder (Dixon *et al*. 1999). However, if multiple interdental spaces are affected, a more conservative approach is warranted because of the high rate (4–47%) of post operative complications following dental extractions (especially multiple dental extractions) in the horse (Prichard *et al*. 1992; Lane 1997; Tremaine 1997; Dixon *et al*. 2000). Therefore, the prognosis is not as good for horses with multiple diastemata, but affected horses can often maintain bodyweight with chopped forage or complete pelleted diets, and regular removal of acquired dental overgrowths. Repeat radiography of younger horses affected by diastemata allows assessment of the progression (or regression) of the condition.

Similarly, other disorders of the cheek teeth such as abnormalities of eruption and wear, and fractured clinical crowns, may be diagnosed by visual examination and digital palpation, but OMO radiographs provide additional information that may assist in planning treatment protocols and assessing prognosis.

In conclusion, the open-mouthed 15º ventrolateral-lateral and 10º dorsolateral-lateral obliques were judged to image optimally the erupted crowns of the mandibular and maxillary cheek teeth, respectively, in the majority of cadaver heads in this study. OMO radiographs are easy to obtain in the sedated patient and can provide valuable additional information in clinical cases where abnormalities of the erupted crown exist.

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