

Equine Odontoclastic Tooth Resorption and Hypercementosis (EOTRH) in Icelandic Horses in Germany: A Correlation Between Clinical and Radiographic Findings

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Abstract

Equine odontoclastic tooth resorption and hypercementosis (EOTRH) is a widespread dental disease with an unknown aetiology, mainly affecting the incisors and canine teeth of senior horses. Being clinically asymptomatic in early stages but progressively destructive and painful in many cases highlights the need for improvements in early diagnosis of EOTRH. This study describes how clinical and radiological findings correlate with distinguishing EOTRH-specific symptoms from non-specific findings. Clinical and radiographic examinations of the rostral oral cavity were performed in 154 Icelandic horses. Each horse received a separate assessment of clinical and radiographic findings and was clinically and radiographically classified as either EOTRH Stage 0 (no findings), Stage 1 (suspicious), Stage 2 (mild), Stage 3 (moderate) or Stage 4 (severe). Analysis revealed statistically significant association between non-age-correlated bite angle, fistulae, gingival swelling, gingival recession as well as gingivitis and radiographic EOTRH diagnoses. Meanwhile, no statistical association was found between the occurrence of calculus or tooth mobility and EOTRH diagnosis. Understanding the interaction of the different symptoms enables further diagnostics (e.g., radiography) to be conducted at an early stage, and therefore EOTRH can be diagnosed and treated at its earliest possible stage.

Keywords

incisor tooth, equine, gingivitis, odontoclastic tooth resorption, hypercementosis, EOTRH

Introduction

The dental syndrome ‘equine odontoclastic tooth resorption and hypercementosis’ (EOTRH) was named due to its histopathological features consisting of a chronological sequence of odontoclastic resorption followed by hypercementosis.¹ This potentially painful and progressive dental disease affects the incisor and canine teeth and less frequently cheek teeth, of senior horses.^{2–4} The aetiology and pathological process of EOTRH is not yet known. Increased age and being male are known risk factors for horses developing EOTRH.^{5,6} Furthermore, place of birth seemed to influence horses in developing EOTRH.⁵ A breed predisposition is also being discussed, as Icelandic horses appear to be more susceptible to EOTRH.⁷ In Germany the prevalence is estimated to be over 50% in older horses.⁸ The occurrence of EOTRH has not been evaluated specifically for Icelandic horses.

Especially at an early stage, EOTRH may be nearly asymptomatic. There is still no evaluation of which clinical signs appear first or which are particularly decisive for the early diagnosis of EOTRH. Clinical signs include gingivitis, gingival recession and subgingival swelling. Furthermore, a reduced ability to grasp carrots and halitosis are also described as

symptoms of EOTRH. In the advanced stage, general condition and behaviour can be severely impaired. It should be noted that even minor signs in the rostral oral cavity can indicate pain in horses.

Besides clinical findings, EOTRH diagnosis is based on radiographic findings, such as variable levels of dental resorption and bulbous enlargement of the intra-alveolar tooth area.^{2,9,10} Widening of the periodontal space as well as tooth fracture, and periapical alveolar bone lysis and bone sclerosis are also typical radiographic findings.^{2,11}

At the present time, extraction of affected painful teeth is the most effective treatment.¹² An understanding of the correlation between clinical and radiographic findings can help to better weigh the decision to extract or not.

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As there is still little knowledge about the aetiology, pathogenesis or disease pattern of EOTRH, the aim of this study was to emphasise the correlation between clinical appearance and radiographic findings to enable the earliest possible diagnosis of EOTRH. Furthermore, it should be evaluated as to which clinical findings are indicative of EOTRH and which are less conclusive.

Material and Methods

History and Physical Examination

A total of 154 Icelandic horses aged 15 years and older were examined. Study participants were recruited randomly within Lower Saxony, Germany.

The horses' previous medical histories were obtained by means of a standardised questionnaire which was filled out by the owner. This included animal husbandry and feeding as well as previous illnesses such as EOTRH and Pituitary Pars

Table 1. Clinical Scoring Chart.

Clinical Findings	Clinical Description of Findings	Score
Fistulae	I purulent or up to 3 serous	1
	2-3 purulent or 4-6 serous	2
	>3 purulent or >6 serous	3
Gingival recession	<1/3 of the root exposed	1
	<2/3 of the root exposed	2
	Whole root exposed	3
Subgingival bulbous enlargement	No	0
	Yes	1
Calculus	<1/3 of the clinical crown covered	1
	<2/3 of the clinical crown covered	2
	>2/3 of the clinical crown covered	3
Gingivitis	Focal	1
	Widespread	2
	Blueish colour	3
Bite angle	15 years old and pincer-like*	1
	Over 15 years old and bisection angle	2
	Over 15 years old and pincer-like*	3
Tooth mobility	No	0
	Yes	1
TOTAL		17
Clinical Stage 0	No clinical findings/healthy	0
Clinical Stage 1	Suspicious	1-2
Clinical Stage 2	Mild	3-5
Clinical Stage 3	Moderate	6-9
Clinical Stage 4	Severe	≥10

Total score of 0 = none of the listed clinical findings. Horses with clinical signs received 1 (mild) to 3 (severe) points per finding, depending on the severity. Horses with one or more movable teeth were given 1 point. The maximum possible score was 17.

*Pincer-like = large angle between the maxillary and mandibular corner incisors.

Intermedia Dysfunction (PPID). Firstly, horses were clinically examined according to a standardised examination protocol. Exclusion criteria were established in advance to ensure that only generally healthy animals were included in further examinations. The subsequent examination of the rostral oral cavity and the intraoral radiographs were performed under sedation.

The investigations took place from October 2020 to December 2021. The study protocol was drawn up with the help of the Animal Welfare Officer of the University of Veterinary Medicine Hannover, Foundation, Hannover, Germany and it was registered as a notifiable animal experiment under file number 33.8-42502-05-20A552 at the Lower Saxonian State Office for Consumer Protection and Food Safety (LAVES).

Clinical Examination of the Oral Cavity

An α-2 opiate combination (detomidine^a (0.012-0.03 mg/kg) and butorphanol^b (0.025-0.04 mg/kg)) were administered intravenously (IV) for sedation. To reduce the horses' chewing activity and tongue movement, midazolam^c (0.02 mg/kg BW) was additionally administered IV if needed.

The clinical appearance of the rostral oral cavity was documented and evaluated according to a standardised score (Table 1). Based on this score, clinical findings were staged as No EOTRH/orally healthy (Total Score = 0, Stage = 0), Suspicious (Total score = 1-2, Stage = 1), Mild (Total score = 3-5, Stage = 2), Moderate (Total score = 6-9, Stage = 3) and Severe (Total score ≥ 10, Stage = 4) (Table 2).

Intraoral Radiography

Digital intraoral radiography of the incisors was made with a minimum of two projections (0°/+45° and 0°/-80°). In some cases, additional oblique radiographs were obtained to secure the diagnosis. A standardised radiological score was established for evaluation including number of affected or missing teeth, tooth shape, structure and surface (Table 3). The radiographs were scored independently by three veterinarians, resulting in three score results for each horse, and these were transformed into a median. This total score based on the median was transferred to an adjusted radiological staging system based on previously published criteria^{8,13} that classified horses into 5 groups: No EOTRH (Stage 0), Suspicious (Stage 1), Mild (Stage 2), Moderate (Stage 3) or Severe (Stage 4) (Table 4).

Table 2. Clinical Staging.

Clinical Stage	Clinical Findings	Score
0	None, healthy	0
1	Suspicious	1-2
2	Mild	3-5
3	Moderate	6-9
4	Severe	≥10

Table 3. Radiological Scoring System.

	Radiological Findings	Score
Quantity: Teeth Affected	0	0
	1-4	1
	5-8	2
	≥ 9	3
Quantity: Missing/Extracted teeth	None	0
	One or more incisors already missing/extracted	1
Tooth Shape	Regular	0
	Preserved: slightly blunted root tip, enlargement of the periodontal space	1
	Largely preserved: circumferential increase of the root tip or the more occlusal part of the tooth, intra-alveolar tooth part < clinical crown	2
	Largely lost: intra-alveolar tooth part = clinical crown	3
	Lost: intra-alveolar tooth part > clinical crown	4
	No radiological findings	0
Tooth Structure	Mild: single area of increased radiolucency (up to max. 1/3 of the root width)	1
	Moderate: multiple areas of increased radiolucency (up to max. 1/3) or two (up to 2/3)	2
	Severe: large areas of increased radiolucency	3
Tooth Surface	No radiological findings	0
	1 irregularity (up to max 1/3 root length)	1
	2 irregularities/surface rough	2
	Obviously irregular (surface slumps)/ rough	3

Tooth Shape, Tooth Structure, Tooth Surface and the Number of Teeth on Which These Findings Were Detected Were Evaluated. The More Advanced the Radiological Findings, the Higher the Scoring. A Maximum of 14 Points Could be Scored.

Table 4. Adjusted Radiological Staging System.^{8,13}

	Stage	Score	
Normal	0	0	No abnormal radiological findings
Suspicious	1	1-2	Tooth shape preserved but sporadic deviations: slightly blunted root tip, surface irregular/rough, slightly altered tooth structure
Mild	2	3-5	Tooth shape preserved, slightly blunted root tip, surface irregular/rough, slightly altered tooth structure
Moderate	3	6-9	Tooth shape largely preserved, intra-alveolar tooth part is not wider than the clinical crown, obviously blunted root tip, surface irregular/rough, moderately altered tooth structure
Severe	4	>10	Loss of tooth shape, intra-alveolar tooth part is wider than the clinical crown, surface obviously irregular/rough, severely altered tooth structure

Statistical Analysis

Descriptive statistics were calculated. Frequency distributions were reported as percentages or numbers. Statistical analysis was performed with standard software^{d,e}.

A scatter plot was created to illustrate the correlation between the clinical and radiological scores. To determine a cut-off in the staging system for differentiating between healthy and diseased horses, the Youden's index (J) was calculated. To assess the correlations between EOTRH diagnosis and the clinical symptoms, logistic regression analysis and the odds ratio estimator (OR) were used. Cramer's V (V) was used to determine the statistical association of variables ($V=0$: no association, $V=0.1$: weak association, $V=0.3$: moderate association, $V=0.5$: strong association, $V=1$: perfect association). A P -value of 0.05 was used to determine significance.

Results

Medical record evaluation included 154 horses, of which 151 met the criteria for inclusion in the final study. Three horses were excluded due to lack of radiographs. The study population consisted of 87 geldings, 1 stallion, and 63 mares that ranged in age from 15 to 31 years, with an average age of 20.1 years.

Clinical Examination of the Oral Cavity

Clinical evaluation showed 11.3% ($n=17$) of horses had no clinical symptoms (Stage 0), whereas 67.5% ($n=102$) were staged as clinically affected by EOTRH. Figure 1 illustrates the percentage distribution of the clinical Stages 1 to 4. Figure 2 summarises the percentage frequency of the clinical symptoms evaluated and their severity. The most common finding was calculus (73.5%), followed by an age-atypical

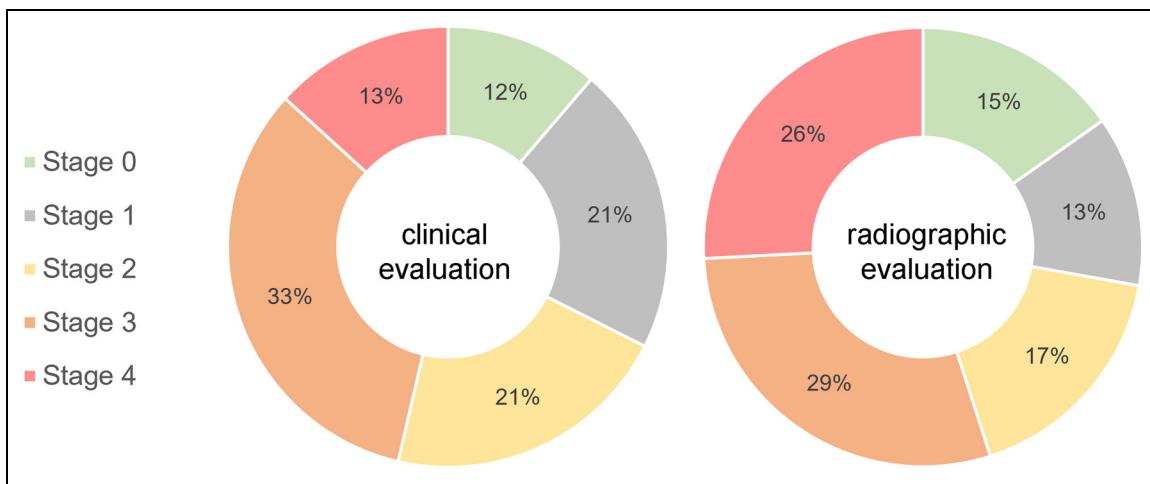


Figure 1. Distribution of EOTRH-stages based on clinical and radiographic evaluation.

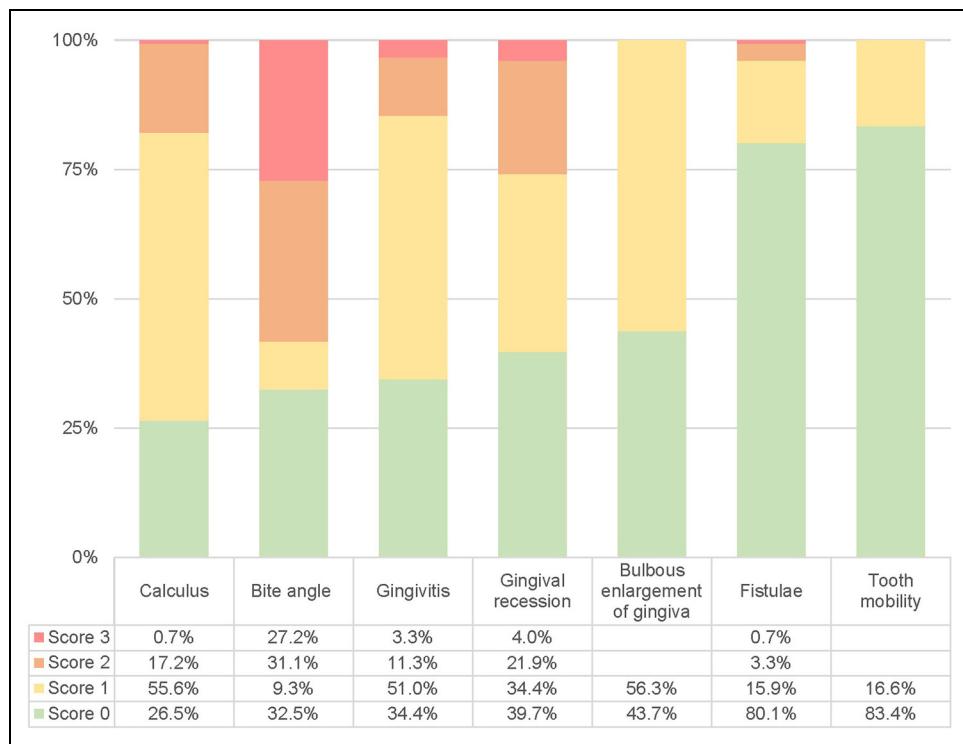


Figure 2. Clinical symptoms and their severity.

bite angle (67.6%), gingivitis (65.6%), gingival recession (60.3%) and bulbous enlargement of the gingiva (56.3%). Fistulae (19.9%) and movable teeth (16.6%) were less frequent.

Evaluation of Radiographs

Radiographic evaluation revealed that 15.2% ($n=23$) of horses were classified as 'EOTRH healthy', while 72.2% ($n=109$) of horses were scored as 'EOTRH diseased'. Further distribution of radiographic stages is given in Figure 1.

Comparison of Clinical and Radiological Staging Systems

Figure 3 provides an illustration of the findings from clinical and radiological examinations from Stages 1 to 4. No fistula formation was detected in horses classified in the 'EOTRH healthy' (radiographic Stage 0) group and the majority (78.3%) showed an age-correlated bite angle. In this group, focal gingivitis (47.8%) and gingival recession (26.1%) were found as signs of inflammation. Bulbous enlargement of gingiva was found in three horses with an average age of 22.3 years (range 17-28 years). In addition, minor



Figure 3. Selected clinical pictures and intraoral radiographs demonstrating typical features of EOTRH. Green arrow - mild calculus. Orange circle - moderate gingival recession. Orange arrow - bulbous enlargement of gingiva. Red line - pincer-like bite angle (not age correlated). Red arrows - all teeth show severe loss of tooth shape and structural alterations. Red dot - tooth 203 is missing.

accumulations of calculus were present in 60.9% ($n=14$) of Stage 0 horses. In one horse not suffering from EOTRH, mobility of all mandibular incisors was observed. The detailed percentage distribution of clinical symptoms is shown in Figure 4. The documented clinical findings within the group ‘EOTRH suspicious’ (radiographic Stage 1) did not differ significantly from the findings in Stage 0 (Figure 5).

Among the 26 horses categorised as radiographic Stage 2 (mild) (Figure 6), there was one horse with some serous fistulae. Furthermore, 50% of the horses showed mild to moderate signs of gingivitis as well as gingival recession (38.5%) and bulbous enlargement of the gingiva (26.9%). Mild to moderate calculus was also detected in more than half of the horses (57.7%). In 52.8% of horses with mild

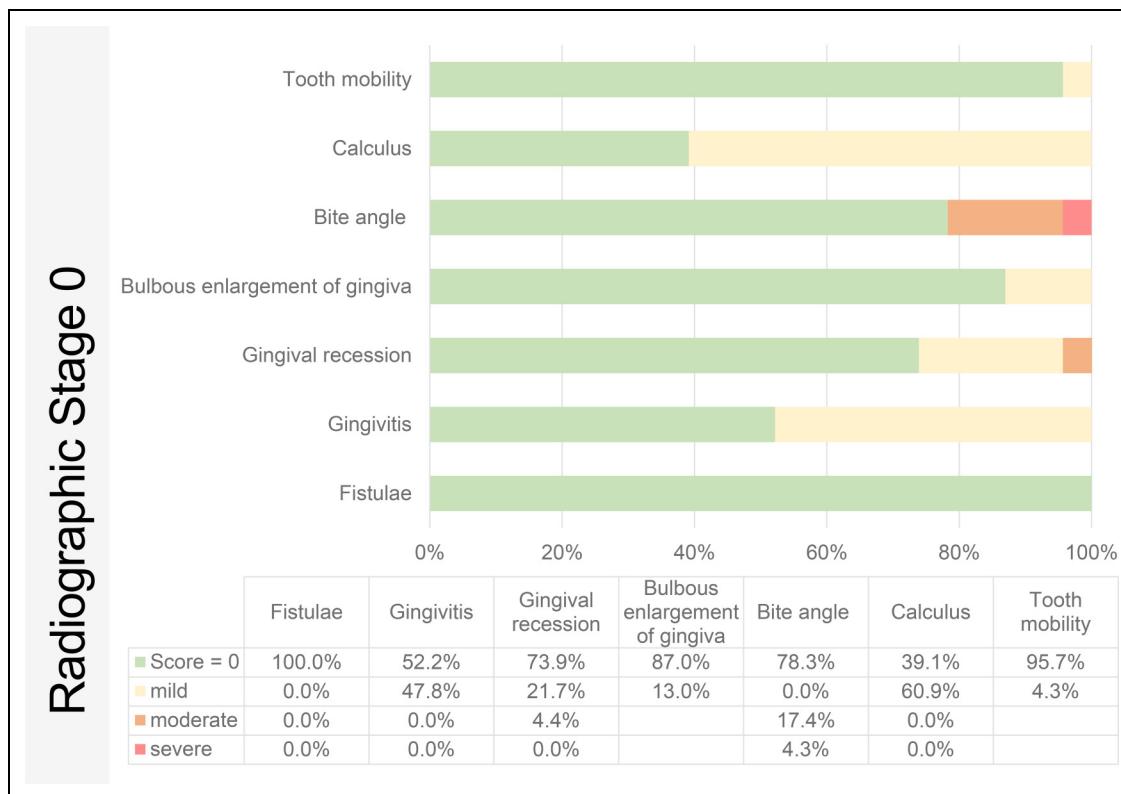


Figure 4. Bar chart and table showing the presence of clinical signs in radiographic Stage 0.

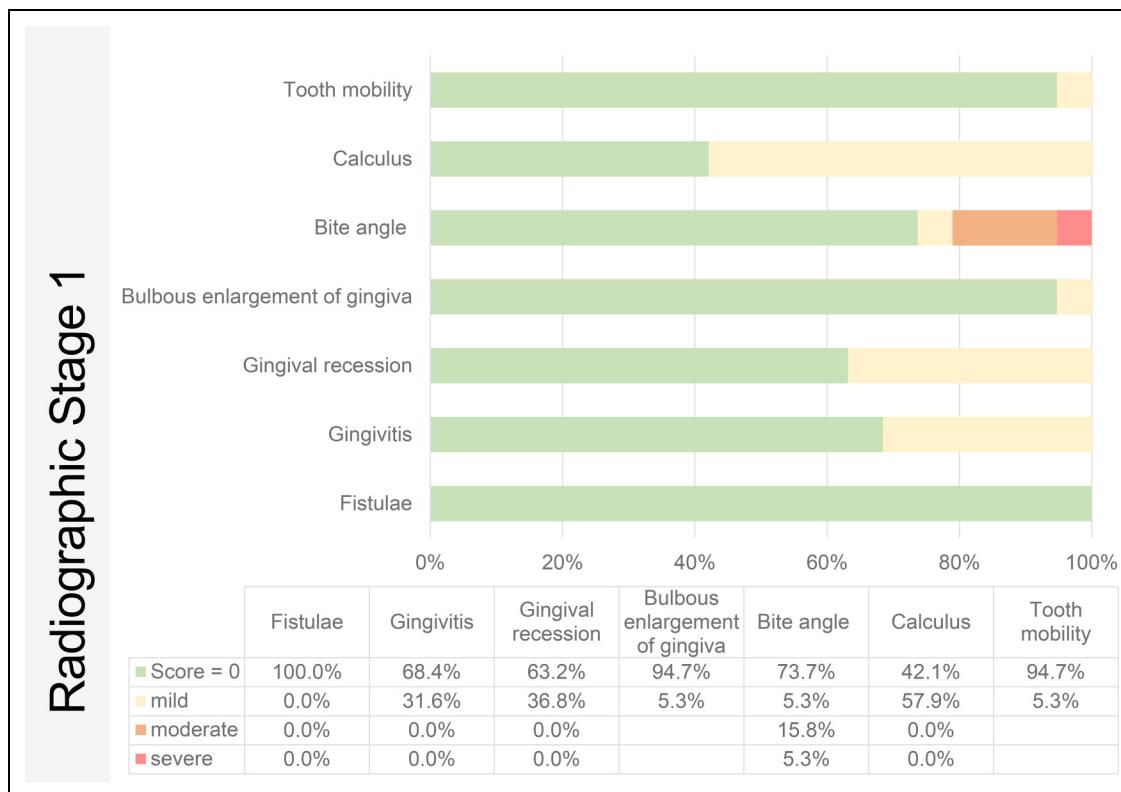


Figure 5. Bar chart and table showing the presence of clinical signs in radiographic Stage 1.

EOTRH the bite angle did not correspond to age. Mobility of one or more teeth could not be detected in Stage 2 'EOTRH diseased' horses.

The 44 horses classified as radiographic Stage 3 (moderate) showed the following signs of inflammation: mild fistula formation (27.3%), mild to moderate gingivitis

(72.8%) and gingival recession (68.2%). In addition, 81.8% of the horses exhibited bulbous enlargement of the gingiva. The bite angle in radiographic Stage 3 was age appropriate in 11.4% of horses and compared to horses classified in radiographic Stage 2 the number of horses with tooth mobility increased (Figure 7).

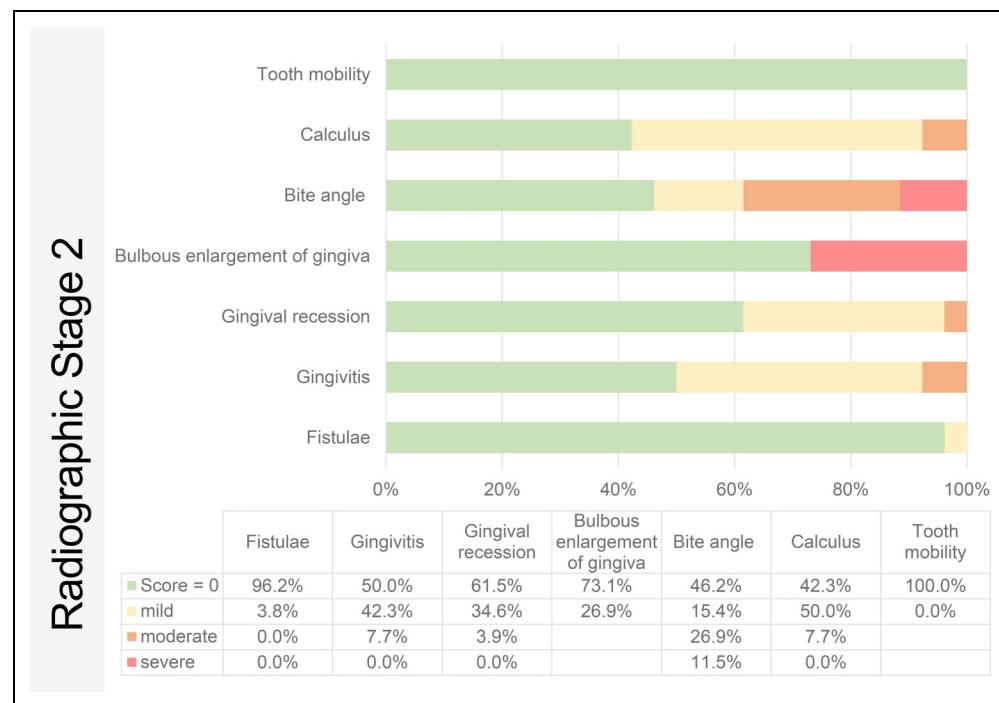


Figure 6. Bar chart and table showing the presence of clinical signs in radiographic Stage 2.

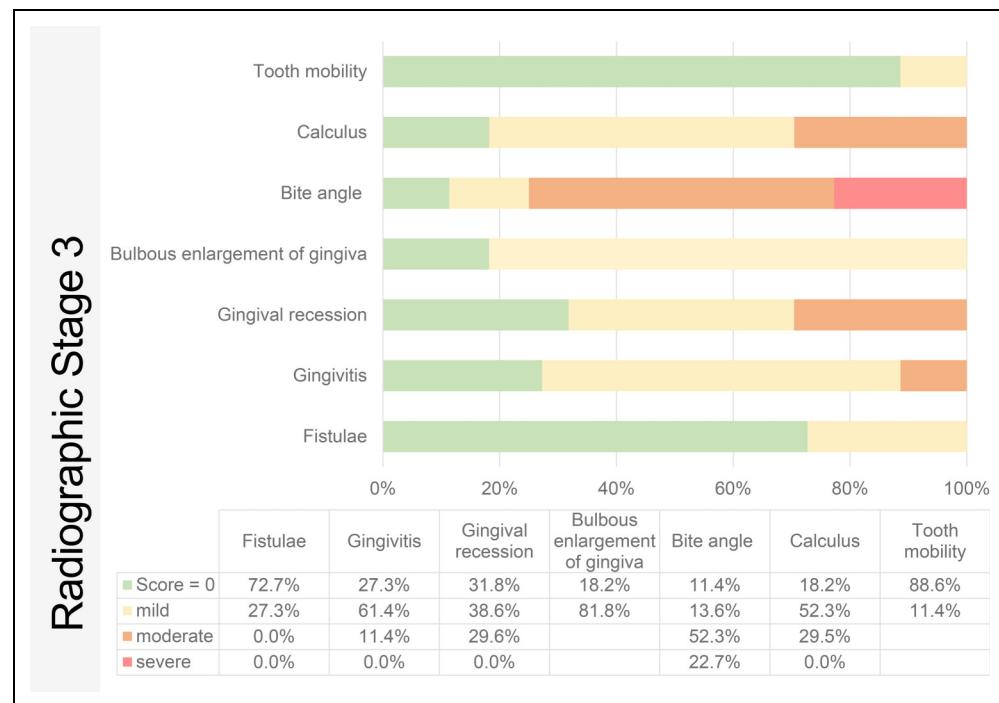


Figure 7. Bar chart and table showing the presence of clinical signs in radiographic Stage 3.

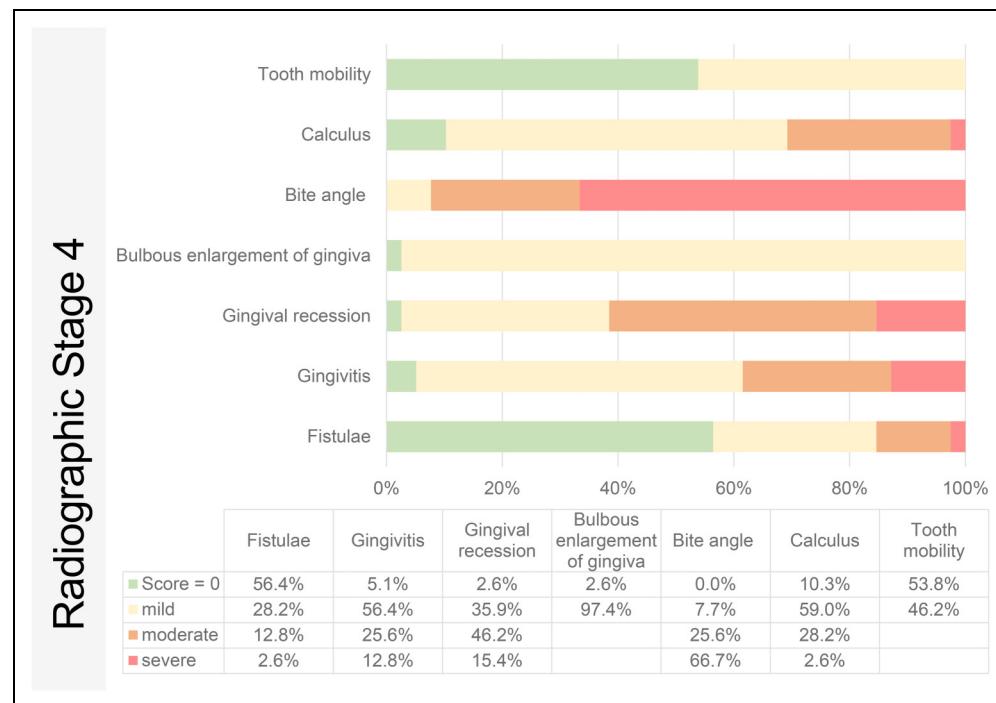


Figure 8. Bar chart and table showing the presence of clinical signs in radiographic Stage 4.

Radiographic Stage 4 (severe) included 39 horses. This group showed mild to severe signs of inflammation of the gingiva such as fistulae, gingivitis and gingival recession (Figure 8). Furthermore, bulbous gingival enlargement was observed in nearly all horses (97.4%) and the bite angle was age-atypical in all horses. Tooth mobility was found in almost half of the horses (46.2%).

Association Between Clinical and Radiographic Findings

The score values of the clinical and radiographic gradings were presented as a scatter plot (Figure 9). Horses not suffering from EOTRH showed a range of clinical scores from 0 to 6. Horses with EOTRH in the ‘mild’ radiographic stage (score = 3-5) were clinically scored 0 to 8 points, while horses in the ‘moderate’ radiographic stage (score = 6-9) received 1 to 13 points. Horses severely affected by EOTRH (score ≥ 10) received clinical scores of 4 to 16 points.

The Pearson’s correlation coefficient of the clinical and radiographic scores was 0.74 ($P < 0.001$) thus more advanced radiographic findings would have a higher clinical score.

Figure 1 shows the percentage distribution of stages 1 to 4 according to both clinical and radiological staging. Cramer’s V showed a moderate statistical correlation between these two staging systems ($V = 0.42$). The highest Youden’s index was calculated for clinical Stage 1 ($J = 0.57$, sensitivity = 0.74, specificity = 0.84), followed by clinical Stage 2 ($J = 0.53$, sensitivity = 0.91, specificity = 0.62).

Logistic regressions also showed a statistically significant influence of bite angle ($P < 0.0001$), bulbous enlargement of

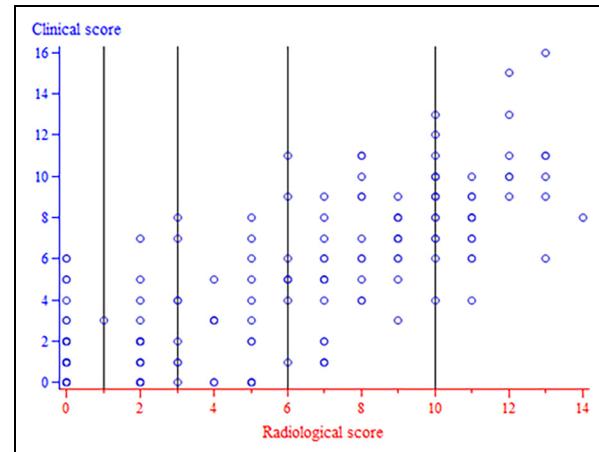


Figure 9. Scatter plot of clinical and radiographic scoring. The vertical black lines mark the cut-off points for the categorisation into stages: Stage 0 = Score 0, Stage 1 = Score 1-2, Stage 2 = Score 3-5, Stage 3 = Score 6-9, Stage 4 = Score ≥ 10 .

gingiva ($P < 0.0001$), gingival recession ($P = 0.0002$) and gingivitis ($P = 0.0113$) on an EOTRH diagnosis by radiography. The odds ratio for EOTRH and age-related bite angle was 0.051 (CI = 0.017-0.157). The same applied to the absence of bulbous enlargement of gingiva (OR = 0.052, CI = 0.014-0.188). Both physiological bite angle and no subgingival swelling were associated with a lower risk of EOTRH diagnosis compared to horses with abnormalities in bite angle and for those with bulbous enlargement of gingiva.

For horses without gingival recession, the odds ratio showed a 0.14-fold lower relative risk of an EOTRH diagnosis ($OR = 0.140$, $CI = 0.051-0.389$). The absence of gingivitis was also associated with a lower risk of an EOTRH diagnosis ($OR = 0.302$, $CI = 0.120-0.762$). Furthermore, a moderate statistical correlation between fistulae and EOTRH diagnosis was shown by Cramer's $V = 0.445$.

Statistically non-significant roles using radiographic EOTRH diagnosis with P values above 0.05 were shown for the presence of calculus ($P = 0.07$) and tooth mobility ($P = 0.09$).

Discussion

Although there are several studies^{8,9,14,15} focusing on clinical and radiographic findings of EOTRH, this is the first study to evaluate the validity and specificity of clinical findings by comparing radiographic results with clinical findings and data obtained from clinical scores.

The dental history of the horses was based on information provided by the owners. This resulted in a study population with a randomly asymmetric distribution of orally healthy horses and horses affected by EOTRH which carried a potential risk of bias because horses presented as healthy were diagnosed with EOTRH during this study. This potentially lead to an over-representation of horses with EOTRH, conversely, it underlined how widespread and underdiagnosed EOTRH is within the German Icelandic horse population.

Although emphasis was placed on good radiographic quality, motion blur could not be avoided in some horses, especially with the owner as an inexperienced assistant. The examinations were performed on an outpatient basis under field conditions, which were sometimes a limiting factor despite adequate sedation. Nevertheless, in most cases it was possible to evaluate the radiographs for signs of EOTRH, otherwise they were excluded from the study. However, minor radiographic changes may have been missed and so there might have been discrepancies within radiographic Stages 1 to 4. Although radiographic quality may have influenced the results, another study showed that EOTRH lesions visible macroscopically and/or on μ CT of extracted teeth may remain undetected on intraoral radiographs.¹⁰

While these factors may have influenced the results, the study showed that some clinical symptoms correlate more strongly with a positive radiographic finding than others. Following a thorough oral examination, horses were categorised as either 'orally healthy', 'EOTRH suspicious' or 'EOTRH diseased'. The orally healthy group had no evidence of fistulae. In addition, it could be shown that horses that clinically showed a non-age correlating bite angle, gingival swelling and recession as well as gingivitis were more likely to have radiographic signs of EOTRH. The presence of calculus or tooth mobility, however, did not correlate with an EOTRH diagnosis.

This leads to the assumption that there is a clinical symptom complex that is indicative of the presence of EOTRH as

follows: non-age correlating bite angle, bulbous enlargement of gingiva, gingival recession, fistulae and gingivitis.

On examination of the distribution of clinical symptoms in the different stages, it was clear that not only the presence but also the severity of clinical findings is an important parameter.

In addition to the combination of several symptoms from the complex already described and the severity of clinical findings, age also plays a role. One study showed that the risk of developing EOTRH increases with age.⁵ Alternatively, EOTRH is a progressive disease, so it is to be expected that symptoms will worsen with age. In addition, there are non-pathological, age-related changes.^{10,16} All these factors result in a higher score. It should therefore be considered whether other threshold values should apply in the staging system for older horses or whether the score values in the clinical score should be adjusted (Table 1). A higher scoring of advanced signs of inflammation (fistulae, gingivitis, gingival recession) would be conceivable to differentiate clinical findings in early stages of EOTRH from aging. At this point, it should be noted that the clinical scoring in this study followed subjective characteristics. For example, no measurement of the bite angle or gingival recession was taken. However, the same person conducted the clinical scoring, thereby increasing consistency and accuracy.

In one study the interincisal angle on radiographs of 33 horses affected by EOTRH was measured.¹⁷ This retrospective study showed no association between interincisal angle and the patient's age, severity or disease pattern of EOTRH. Although this study was unable to detect an association between changes in bite angle and severity of EOTRH, the present study shows a significant association between EOTRH and non-age correlating bite angle ($P < 0.0001$, $OR = 0.052$).

Calculus and tooth mobility appeared to not be significant symptoms of EOTRH in the population studied. In the case of calculus, this may be because its formation is promoted by a range of factors, such as the feed. Calculus alone does not indicate EOTRH, but it can be assumed that painful changes in the incisors results in a higher salivary flow which leads to increased accumulation of calculus. Moderate to severe calculus as a secondary symptom of advanced EOTRH (Stage ≥ 3) was found in more than 80% of the affected horses in this study.

Tooth mobility can also be a symptom of advanced EOTRH. Alternatively, increased mobility is also found in individual tooth disease or in diseases of the maxillary or mandibular bone. Thus, while calculus level and tooth mobility can be secondary to EOTRH, they are not particularly indicative of the disease.

In conclusion, it is a combination of findings of the symptom complex (e.g., fistulae and non-age correlating bite angle, considering severity and age), which should prompt radiographic examination to confirm the diagnosis of EOTRH and that this complex of symptoms is required to clinically indicate EOTRH. The sole occurrence of gingivitis or gingival recession can also be non-specific symptoms and may be the result of periodontitis. Conversely, not every pathological finding on the incisors and their surroundings necessarily indicates EOTRH.

Materials

- (a) Cepesedan, CP-Pharma Handelsgesellschaft mbH, Burgdorf, Germany.
- (b) Butorgesic, CP-Pharma Handelsgesellschaft mbH, Burgdorf, Germany.
- (c) Midazolam B. Braun Melsungen AG, Melsungen, Germany.
- (d) SAS-EG version 7.15 with SAS software 9.4, SAS Institute, Cary, NC, USA.
- (e) Excel version 2304, Microsoft Corp, Seattle, WA, USA.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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