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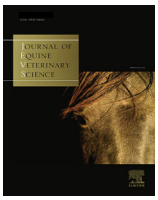

Original Research

Behavioral Signs Associated With Equine Periapical Infection in Cheek Teeth

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ABSTRACT

No studies have focused on dental pain signs associated with periapical infection in cheek teeth (CT) of horses. Moreover, the ability of owners to recognize signs of dental pain in horses has not been reported. We hypothesized that periapical infection will usually induce pain that manifests in the behavior of the horse. Removing the infected tooth will reduce the expression of such behaviors. Owners of 47 horses whose CT had been removed because of periapical infection participated in this study. They filled an internet-based questionnaire including 23 questions about eating behavior, bit behavior, and general behavior observed before and after the operation. The number of signs exhibited by each horse before and after CT removal was compared using Wilcoxon signed-rank sum test. Values of $P < .05$ were considered significant. Before the operation, avoidance behaviors, such as evading the bit, difficulties in eating, and even asocial or aggressive behaviors were commonly reported by the owners. Removing the infected tooth significantly reduced the number of these behavioral patterns expressed by the horses ($P < .001$ for each group of behaviors), suggesting that they could be associated with dental pain. Half of the cases had been diagnosed during a routine dental examination, indicating that many owners did not realize that certain undesirable behavioral patterns of their horses might be associated with dental pain. These findings highlight the importance of training owners to recognize behavior potentially related to dental pain in horses and that routine dental examinations are essential for ensuring horses' well-being.

1. Introduction

Periapical infections of the cheek teeth (CT) are common in horses [1]. In this article, the term "periapical infection" refers to bacterial infection of the dental apex, and it is used as a synonym for apical infection and apical periodontitis with or without concurrent pulpitis, abscess formation, osteitis, and sinusitis. Reported signs of equine periapical infection often include quidding, weight loss, external swelling, nasal discharge, epiphora, halitosis, external sinus tracts, and bitting or head carriage problems [1,2]. Other commonly reported behavioral indicators of head and dental pain in horses are headshaking, food pocketing [3], slow eating, abnormal head posture when eating, and long strands of forage and undigested whole-grain particles in feces [2]. However, these signs are nonspecific and may also be associated with other issues not related to teeth. Furthermore, the signs may start gradually which makes it difficult for owners to notice them.

In man, pulpitis and apical infection can induce varying pain, which can be continuous or intermittent, acute or chronic, and range from none to severe [4]. The symptoms depend on the disease process, alterations in the virulence and number of microbes, and host resistance [4]. In general, if a condition is painful in man, it can also be expected to be painful in animals [5]. Moreover, in horses, pulp may be exposed during excessive dental floating [6–9], which has been suggested to cause pain [2,9]. Nevertheless, the horse has hypsodont teeth and the anatomy differs from brachyodont human teeth. Therefore, direct assumptions of similarities in pulpal or periapical pain between these two species might not always be justified.

Animal welfare/ethical statement: The research related to animal use was conducted in compliance with all of the relevant national regulations and institutional policies for the care and use of animals (University of Helsinki Viikki Campus Research Ethics Committee, 4/2017, 23.5.2017).

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As in many other animal species, pain in horses may be difficult to notice. Horses may suppress the exhibition of obvious signs of pain, as has been suggested with many prey species [10]. Clinical evaluation of pain in animals is also a subjective procedure, dominated by personal bias, perception, and philosophy [11–13]. Thus, the assessment of horses' well-being varies among caretakers and owners [14], but also among veterinarians [15,16]. Owners often seek veterinary attention only after the horse exhibits obvious clinical dental problem signs such as malodorous nasal discharge, facial swelling, weight loss, anorexia, and draining sinus tracts [1]. These signs reflect an advanced dental disease state [17], which likely already caused pain at an earlier stage. Therefore, not recognizing all of the signs and behavioral changes caused by periapical pain may prolong the time to seeking treatment, causing the horse unnecessary suffering. Currently, it is not known whether chronic dental pain in horses is subtle, underdiagnosed and overlooked, or whether equine periapical infections truly remain asymptomatic before the onset of obvious physical signs. To the authors' knowledge, no studies focusing on owners' perception of signs of equine periapical dental pain have been published.

This study hypothesized that periapical infection usually causes pain that manifests in the behavior of the horse. Removing the infected tooth will thus reduce the expression of such behaviors. Furthermore, we assumed that the owners can perceive a difference in the behavior of the horse after CT removal. The behavioral changes noticed by the owners could help to distinguish possible signs of pain induced by periapical infection in horses. If the behavioral changes characteristic to pain induced by equine periapical infection were better recognized, the owners could be advised to suspect the condition earlier, facilitating earlier diagnosis and treatment.

2. Materials and Methods

2.1. Study Design

Owners assessed horse behavior before and after CT removal in this retrospective, questionnaire-based study.

2.2. Horses

The sample comprised referral and first opinion cases of a private equine dental clinic. Inclusion criteria for the horses were diagnosis of periapical infection in one or multiple CT and CT removal between September 2016 and February 2018 at the clinic. The horse was excluded if it had not healed from CT removal at follow-up, if it was on a continuing course of nonsteroidal anti-inflammatory drugs, if it had an acute dental fracture or if the owner reported in the questionnaire a chronic health issue in their horse which might cause similar signs as dental pain. Furthermore, the horse was excluded if it had a remaining dental problem which was likely to cause pain after the CT removal, such as radiological evidence of periapical infection, in a tooth other than the removed one. Data on horses' clinical signs, diagnoses, treatments, complications, and outcome were collected from electronic case records.

2.2.1. Ethics Approval

The research related to animal use was conducted in compliance with all of the relevant national regulations and institutional policies for the care and use of animals (University of Helsinki Viikki Campus Research Ethics Committee, 4/2017, 23.5.2017).

2.2.2. Examinations

All of the horses were examined under sedation with intraoral endoscopy by a single veterinarian experienced in equine dentistry. Skull radiography was performed to confirm the diagnosis of periapical infection in standing, sedated horses in an 80 mA and 100 kW x-ray unit and using a direct digital radiography system (Pixium 2430 EZ, Thales Electron devices, France). In cases with suspected maxillary CT infection, laterodorsal-lateroventral oblique projections of each maxillary arcade were obtained. A lateral projection of the head was obtained if sinusitis was suspected. For cases of suspected mandibular CT infection, lateroventral-laterodorsal projections of the mandibular arcades were obtained. If periapical infection was confirmed, CT removal was recommended even if the owner had not noticed evident signs of dental pain in the horse.

2.3. Treatments

A standing oral extraction of CT was performed on all horses under sedation with a procedure described by Dixon et al. [1]. Before the operation, horses received flunixin meglumine (Flunixin vet, Schering-Plough Santé Animale, France) and penicillin G (Geepenil vet, Orion, Finland) intravenously (IV). A local maxillary, mandibular, or inferior alveolar nerve block was performed before the procedure. Horses received a loading dose of detomidine (Domosedan, Orion, Finland) and butorphanol (Torbugesic, Zoetis Finland, Finland) IV after a constant rate infusion of detomidine and butorphanol IV and crystalloids IV throughout the procedure. After dental extraction *per os,* horses had a vinyl polysiloxane (President putty, Coltene, Switzerland) plug inserted into the alveolus and a five-day course of trimethoprim-sulfadiazine (Oriprim, Orion, Finland) and meloxicam (Metacam, Boehringer Ingelheim Vetmedica GmbH, Germany). Pelleted hay was recommended for one week. Horses were re-examined after 7–10 and 18–21 days, and the plug was changed. If the alveolus had healed on a normal schedule, horses could be ridden with a bit 3 weeks after the dental extraction, except for horses whose triadan position 06 tooth was removed, in which case, riding was allowed 4–5 weeks after extraction.

2.4. Questionnaire

The internet-based questionnaire including instructions on how to answer was sent once to 93 owners *via* e-mail between September 2017 and April 2018, a minimum of seven weeks and a maximum of 11 months after CT removal. If the horse had had complications after CT removal, the questionnaire was sent six weeks after the alveolus had been deemed healthy. The questionnaire was written in Finnish, which was the mother tongue of the respondents. It contained background questions and altogether 23 questions about eating behavior, bit behavior, and general behavior before and after CT removal (Supplementary file, Tables 1–4). Most of the signs related to eating and bit behavior have commonly been associated with equine dental pain [1–3,18,19] and some were based on the authors' own observations. The general behavioral signs have been associated with various painful conditions in horses [20–26]. Response options were yes, no, and I do not know. It was possible to expand on the signs in an open text box at the end of the questionnaire.

Informed owner consent was obtained at the end of the questionnaire.

2.5. Data Analysis

The answer "I do not know" to a tick box question was recorded as that sign had not been noticed. Thus, the answer "yes" was converted to number 1 and the answers "no" and "I do not know" were converted to number 0 for the statistical analyses. The numbers of horses showing or not showing each sign before and

Table 1
Signs related to eating and drinking behavior reported by the owners of 47 horses before and after cheek tooth removal due to periapical infection.

Sign	Before		After		
	No	Yes	Quit	Did not quit	Started
Adjusts hay in mouth when eating	26	21	16	5	0
Eats hay slowly	28	19	16	3	1
Drops hay from mouth	28	19	16	3	1
Keeps pausing while eating hay	29	18	14	4	0
Food pocketing	31	16	14	2	2
Turns head while eating hay	32	15	13	2	1
Drops grain from mouth	33	14	9	5	0
Dips hay in water	36	11	9	2	0
Avoids drinking cold water	36	11	6	5	0
Total number per horse median (minimum–maximum)	3 (0–8)		0 (0–5)[a]		

[a] significantly different from "before".

after CT removal were cross-tabulated. The numbers of behavioral signs before and after CT removal were compared within three categories of behavioral signs: eating and drinking, bit behavior, and other behavioral signs. Independent samples Mann–Whitney *U*-test was also used to compare numbers of behavioral signs in horses with and without obvious external signs of periapical infection. Furthermore, the same test was used to compare the amount of eating behavior changes before CT removal between horses that gained and did not gain weight after CT removal. Kruskal–Wallis test was used to compare differences between the numbers of behavioral signs in three groups based on the indication of the initial dental examination: 1) routine dental examination, 2) dental examination due to signs that the owner had not connected to dental problems, and 3) dental examination due to specific signs that had made the owner suspect a dental problem.

The numbers of signs associated with eating and drinking, use of the bit, and other behavior observed before and after CT removal were compared within horses with related samples Wilcoxon signed-rank test. Values of $P < .05$ were considered statistically significant.

3. Results

The questionnaire was sent to 93 owners, 58 of whom replied (62.3%). One of the owners did not give permission to use the information in this study. Four horses had not fully recovered from CT removal by the time their owner answered the questionnaire, and one horse had an acute dental fracture. Three horses had chronic gastrointestinal problems, and two horses had such a problem in a tooth other than the removed one which was likely to cause pain. These 11 horses were excluded from the data. Thus, data remained for 47 horses. Eight horses were not ridden with a bit or were not exercised at all. Thus they were excluded from the analysis of bit behavior.

Age of the horses ranged from 4 to 26 years (median 13 years, interquartile range 10–16 years). Their breeds were warmbloods (n = 26), ponies (n = 8), Finnhorses (n = 5), Standardbreds (n = 3), and other breeds (n = 5). They were used mainly for riding (n = 40), but there were also a few trotters (n = 2), brood mares (n = 2), and horses retired from work (n = 3). Gender distribution was 26 females and 21 males (18 geldings and 3 stallions). The time between CT removal and questionnaire response ranged from 53 to 399 days (median 144 days, interquartile range 94–253).

3.1. Diagnosis

The diagnosis of periapical infection was determined by clinical signs, oral findings, and complementary radiographs. Forty-six of the horses had at least one oral finding on the diseased CT such as a fracture or a fissure fracture of teeth, caries lesion, occlusal pulpal exposure, or a draining fistula. In one horse, the diseased CT was dislocated, but the teeth were otherwise normal. Forty-six horses had radiographic evidence of periapical infection such as periapical destruction and radiolucency, periapical sclerosis, periapical halo formation, clubbing of tooth root, widening of periodontal space, loss of *lamina dura denta*, and excessive periapical cementum deposition. One horse had no radiographic evidence of periapical infection, but had occlusal pulpal exposure and discharging fistulae next to a diseased CT. All of the removed teeth were examined after extraction and all deemed abnormal, with purulent necrosis of the apical area and/or necrotic pulp, inflamed soft tissue around the apices, and/or fibrous tissue protruding from apical foraminae.

From the 47 horses included in the final data, altogether 65 teeth were removed. Thirty-nine were maxillary CT, most of which were at triadan position 09 (n = 23). The rest of the teeth (n = 26) were mandibular CT. In the removed teeth, periapical infection was associated with dental fracture with or without predisposing caries

Table 2
Bit behavior signs reported by the owners of 39 horses before and after cheek tooth removal due to periapical infection.

Sign	Before		After		
	No	Yes	Quit	Did not quit	Started
Evades the bit: Grabs the bit, is above the bit, runs through the bit	15	24	21	3	0
Difference between left and right rein contact when ridden or driven with a bit	11	28	16	12	0
Headshaking when ridden/driven with a bit	21	18	15	3	0
Rein contact worse on the same side as the affected tooth	17	22	14	8	0
Horse opens its mouth when ridden/driven with a bit	21	18	11	7	0
Resists bridling	33	9	7	2	0
Lolling tongue when ridden/driven with a bit	34	5	5	0	0
Total number per horse median (minimum–maximum)	3 (0–7)		1 (0–3)[a]		

Eight horses have been excluded from the table because five were not exercised at all and three were ridden only without a bit, and thus, their bit behavior could not be assessed by the owner.

[a] significantly different from "before".

Table 3
General behavior signs reported by the owners of 47 horses before and after cheek tooth removal due to periapical infection.

Sign	Before		After		
	No	Yes	Quit	Did not quit	Started
Withdrawn or intense stare	30	17	17	0	0
Asocial behavior with people	32	15	13	2	0
Asocial behavior with other horses	38	9	8	1	0
Aggressive behavior	39	8	7	1	0
Head shy	35	12	6	6	0
Not interested in surroundings	36	11	6	5	0
Self-mutilation of head	43	4	4	0	0
Total number per horse median (minimum–maximum)	1 (0–5)		0 (0–2)[a]		

[a] significantly different from "before".

lesions (n = 32), complicated fissure fracture (n = 6), deep periodontal infection due to diastema with or without supernumerary teeth (n = 14), deep dental caries (n = 1), and an apical abscess (n = 4). In eight cases, the periapical infection was due to pulpitis without other dental abnormalities. In all horses, the dental problem was chronic.

According to patient records, 6 horses (13%) had obvious external signs of periapical infection manifested as sinusitis (n = 2), external swellings (n = 6), and/or draining fistulae on skin (n = 3). Horses were divided into two groups: those with obvious external signs of periapical infection (n = 6) and those without external signs (n = 41). No significant differences were detected between these two groups in the numbers of behavioral indicators.

According to the answers in the questionnaire, periapical infection was diagnosed during a routine dental examination in 26 horses (55%) and during examination for nonspecific signs in 14 horses (30%). Periapical infection was diagnosed due to obvious signs of dental problems in seven horses (15%). No significant differences were detected between the indications of the initial dental examination in the total numbers of behavioral signs reported by the owners ($P > .05$).

3.2. Other Treatments

Two horses had had debridement and filling of carious grade 3 infundibula (modified Honma system [27]) in another tooth soon after CT removal. The procedure was performed as described by Horbal [28]. Two horses had pulp restoration soon after CT removal in a tooth other than the extracted one. Furthermore, in one horse, orthograde endodontic treatment was performed because of pulpitis in another tooth soon after CT removal. The procedure was performed as described by Lundström [29]. Eight horses had a routine dental floating done at the same time as the CT removal. No other dental or other procedures were performed on the horses.

3.3. Alleviation of Symptoms

Of the owners, 45 (96%) reported that their horse had gained benefit from the CT removal and two (4%) reported no benefit. The number of behavioral signs reduced significantly ($P < .001$) after CT removal in every category (Tables 1–4). Before CT removal, 36 owners (77%) had noticed one or more signs related to eating and drinking behavior (Table 1). The number of such signs was reduced in 31 horses (86%), including 18 (50%) owners who no longer observed any eating or drinking behavior signs after CT removal. Five owners reported an eating behavior sign that started after CT removal. Thirty-four owners (87%) had noted one or more problems related to bit behavior before CT removal, 30 of whom (88%) reported fewer signs after CT removal, including 13 owners (38%) who no longer saw any bit behavioral signs after CT removal. No novel bit behavioral problems had emerged after CT removal (Table 2). Thirty-four owners (72%) had noted one or more alterations in general behavior before CT removal (Table 3). In 27 horses (79%), the number of alterations was decreased, including 21 horses (62%) with no general behavioral signs detected after CT removal. No owners reported a sign related to general behavior that had started after CT removal. Thirty owners (64%) had observed one or more of the miscellaneous signs listed in Table 4 in their horse before CT removal. Twenty-two (73%) of these owners no longer saw these problems after CT removal, but two owners reported such a sign starting after CT removal. Moreover, two owners reported their horse to have unilateral nasal discharge only after CT removal, but according to patient records these horses stopped showing this sign before the last control visit.

The owners reported that 15 horses (32%) had lost weight before the CT removal, 14 of which gained weight after CT removal. Furthermore, five horses that had not lost weight before CT removal had gained some weight after it; hence, altogether, 20 horses (43%) gained weight after CT removal. No owner reported that their horse had lost weight after CT removal. The median of eating behavioral signs before CT removal was 1.5 (0–7) in horses that did not gain weight. In horses gaining weight, the median of eating behavioral alterations was 5 (0–8) before CT removal. Horses that gained weight had had significantly more eating behavioral problems before CT removal than horses not gaining weight ($P = .003$).

In the open box answers, 14 owners (30%) characterized their horse as being more positive, satisfied, and social after CT removal. Three owners reported that the horse had been dangerous to ride before CT removal; horses had been timid and had bucked often, but after CT removal, they had been safe to ride. Hair and skin

Table 4
Miscellaneous signs reported by the owners of 47 horses before and after cheek tooth removal due to periapical infection.

Sign	Before		After		
	No	Yes	Quit	Did not quit	Started
Halitosis	25	22	21	1	1
Poor performance[a]	33	8	8	0	1
Long strands of forage/whole-grain particles in feces	38	9	6	3	0

[a] Data of five horses are missing because they were not exercised and therefore their performance could not be evaluated.

condition had improved in three horses. One horse had had chronically loose feces, the condition improving after CT removal according to the owner.

Owners of two horses reported no signs before CT removal. Both horses had a fractured CT, and the periapical infection was noticed during a routine dental examination. One of these horses had severe lysis in the root of the fractured tooth and a sinus fistula from a dental alveolus, which was observed during CT removal. This horse had no other dental problems. After CT removal, the horse had transient unilateral nasal discharge and malodorous breath, which the owner had not noticed before CT removal. The other horse had periapical infection in two CT due to deep caries; one of these teeth had also been fractured. This horse also had grade 3 caries change in other tooth, which had not been treated by the time that the owner answered the questionnaire. These dental problems might have had an impact on this horse's behavior after CT removal.

4. Discussion

We studied the manifestation of pain caused by periapical CT infection in the behavior of the horse. The owners of the horses reported that the number of behavioral changes related to eating, use of bit, and general behavior of the horse reduced significantly after CT removal, indicating that these horses may have been experiencing dental pain.

Most of the behavioral signs related to eating and drinking that were included in our questionnaire have commonly been associated with dental pain [1–3,18,19], and at least some of them were reported by most of the owners. Almost half of the horses gained weight after CT removal, and the same horses also had significantly more signs related to eating behavior before the operation than horses that did not gain weight. This suggests that in many horses, chewing was probably so painful before CT removal that it hindered their ability or willingness to masticate properly. The CT removal presumably enabled more thorough chewing, leading to better digestibility and increasing the total amount of feed that the horse could eat. This assumption is supported by previous studies demonstrating associations between dental health, fecal particle size, and digestibility of feed, although these studies focused mainly on the impact of dental floating in horses with only mild to moderate dental problems and their results were contradictory [30–35]. In our study, only a few owners had noticed long strands of forage or whole grain in the feces of their horses, but some owners may not observe the feces very closely. Furthermore, Dixon et al. [1] described weight loss as an unusual symptom of dental-related pain. Usually, such horses spend a longer time eating, and weight loss occurs only in extreme cases [2]. However, in this study, the owners were asked whether the horse had gained weight after CT removal, not whether the horse had a poor body condition before CT removal. Therefore, it is not known how many horses were actually particularly thin.

In this study, bit-related behavioral problems seemed to be more common than signs related to eating and drinking in horses suffering from periapical dental pain. However, bit-related problems may be easier for the owner to notice because most of them probably exercise the horse more often than observing its eating behavior. Evading the bit and differences between rein contacts were the most common signs within bit-related behaviors in this study. Almost all signs included in our questionnaire have also been reported as bit-induced behaviors [19]. Although riding with a bitless bridle can alleviate signs of bit-related pain [19], distinguishing horses with dental pain from horses with merely bit problems requires a thorough dental examination. Approximately, one-third of the horses shook their head when exercised, and most of them improved after CT removal, suggesting that dental pain may also cause signs resembling a headshaker. Therefore, a careful dental examination should also be included in the diagnostic protocol of headshakers.

The undesirable behaviors reported often made the horse unpleasant to ride and handle. After CT removal, there was a notable decrease in the number of horses that evaded the bit when ridden or driven, were head shy, resisted bridling, or were unsocial with people or with other horses. Furthermore, some owners reported a positive change after CT removal in horses that had been timid and bucked often during riding. All of these signs could easily be regarded as misbehavior or inadequate training of the horse. Avoidance behavior mimicking misbehavior has also been suggested in horses with chronic foot [36] and neck pain [20], but not with dental pain. In addition, all but one of the eight horses displaying aggressive behavior and all manifesting self-mutilation of the head ceased such behavior after CT removal. The association between chronic pain and aggression has been suggested in horses with chronic vertebral pain [21], and self-mutilation has also been linked to pain [22]. To the authors' knowledge, this is the first time that aggressive behavior toward self or others has been associated with dental pain in horses.

Although the owners had probably not been trained to evaluate the pain grimace scale [23–26], many of them reported a withdrawn or intense stare in their horse before CT removal. None of the horses displayed it after the operation. This sign, referred to as one of the typical facial expressions of pain in horses, was first described with acute somatic pain [23]. It has since also been reported with musculoskeletal pain [24], acute colic [25], and head pain [26]. The population with head pain consisted of horses with acute and chronic head trauma and uveitis, but also some with alveolitis [26]. Our results support the finding that dental pain may also induce a withdrawn gaze.

Halitosis was the most common physical sign reported by the owners. In addition, unilateral nasal discharge, mandibular sinus tracts, and external swelling, which are commonly reported external signs of periapical infection [1], were seen in some horses. These obvious external signs are probably easier to detect than behavioral signs, but they usually represent an advanced stage of infection. However, as the number of behavioral alterations did not significantly differ between horses with and without these external signs, horses probably exhibit pain before external signs of periapical infection occur. Thus, early diagnosis in equine periapical infection is important to avoid prolonged pain and suffering in horses.

In general, the vast majority of the owners considered that their horse had benefitted from the CT removal. Some owners had also observed an improvement in the horses' performance after CT removal. Thus, dental pain should be kept in mind as a differential diagnosis with poorly performing horses. No novel bit behavior or general behavior signs induced by the CT removal were reported. A few owners reported other undesirable behavioral signs that had started after CT removal such as food pocketing, dropping of hay, slow eating, head turning when eating, and poor performance. These signs may indicate pain, discomfort, or complications related to CT removal. For example, food pocketing may arise for mechanical reasons, as CT removal creates a big diastema in which hay may accumulate. Moreover, a few owners observed novel, transient signs, such as halitosis and unilateral nasal discharge, probably related to infection. However, such complications were quite uncommon, as in earlier reports using an intraoral extraction technique [37]. A four-week alveolar filling time with healthy granulation tissue has been reported after CT repulsion under general anesthesia [38]. In our study, a less-invasive intraoral CT removal technique was used, and alveolar healing time of four weeks was sufficient based on our clinical experience. We therefore

anticipated that the horses would have been painless long enough for the owners to observe signs seven weeks after CT removal, when the questionnaires were sent at the earliest.

As expected, the periapical infections were often incidental findings during a routine dental examination suggesting that many of the owners had not suspected a dental problem as the reason for undesirable behavioral patterns. Horses with periapical infection noted during a routine dental examination had not shown significantly less behavioral signs associated with dental pain than horses with an owner-suspected dental problem. Either owners did not link the behavioral signs to dental pain or the signs of pain were overlooked by the owners. Therefore, routine dental examinations seem to be essential for ensuring horses' well-being even if the owner does not report signs of dental pain. Overall assessment of the horse requires an observer who is familiar with the horse, but underestimation of well-being impairment among horses' caretakers has also been suggested [14]. For example, in dogs, many signs of pain were recognized by the owners only after they had been presented with a leading question by the veterinarian or after a period of successful pain relief when the dogs' behavior changed noticeably [39]. On the other hand, estimation of chronic pain correlated well between dog owners and veterinarians if the owners were trained to recognize it [39]. Our findings highlight the importance of training owners and caretakers to recognize behavior related to dental pain in horses.

As this study was based on a questionnaire, there were possible sources of bias. In general, answers to questionnaires may reflect subjectivity of the human respondents [40]. On the other hand, we were intended to collect data about behavioral signs of periapical CT infection in horses on owners' perception and a questionnaire was a viable option for this purpose. Furthermore, we cannot rule out the possibility that some of the horses may have had other painful conditions not related to the removed CT possibly affecting their behavior. Moreover, no randomization or placebo controls could be used for practical or ethical reasons, and the owners replied to the questionnaire only after CT removal. Therefore, it is not known which signs the owner had noticed before and which ones only after they had disappeared after CT removal. A study design where owners reply to the questionnaire twice, before and after CT removal, would reveal more about which signs the owners likely miss or fail to recognize as signs of pain. On the other hand, it might have been more difficult to reach the same owners and to motivate them to answer the questionnaire twice, which would have reduced the number of adequate cases.

5. Conclusions

Our findings indicated that periapical infection probably causes pain in horses, as removing the infected tooth significantly reduced the expression of behavioral signs related to eating, riding and handling of the horses reported by the owners. However, many owners did not seem to realize that certain undesirable behavioral patterns in their horses might have been associated with dental pain. Thus, there is an obvious need to train owners to recognize pain-related behavior in their horses. Furthermore, routine dental examinations are essential to ensure horses' well-being. Thorough examinations to check for periapical infections may be justified even if the owner does not report signs of dental pain.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jevs.2019.03.005.

References

[1] Dixon P, Tremaine W, Pickles K, Kuhns L, Hawe C, McCann J, et al. Equine dental disease part 4: a long-term study of 400 cases: apical infections of cheek teeth. Equine Vet J 2000;32:182–94.
[2] Dixon PM. A review of equine dental disorders. Vet J 2005;169:165–87.
[3] Ashley F, Waterman-Pearson A, Whay H. Behavioural assessment of pain in horses and donkeys: application to clinical practice and future studies. Equine Vet J 2005;37:565–75.
[4] Rosenberg PA. Pulpal and periapical diagnostic terminology and treatment considerations. In: Endodontic Pain. Berlin: Heidelberg: Springer; 2014. p. 71–90.
[5] American College of Veterinary Anesthesiologists' position paper on the treatment of pain in animals. http://www.acvaa.org/docs/Pain_Treatment; 2006. [Accessed 30 October 2018].
[6] Bettiol N, Dixon PM. An anatomical study to evaluate the risk of pulpar exposure during mechanical widening of equine cheek teeth diastemata and 'bit seating'. Equine Vet J 2011;43:163–9.
[7] Dixon PM, Hawkes C, Townsend N. Complications of equine oral surgery. Vet Clin North Am Equine Pract 2008;24:499–514.
[8] Marshall R, Shaw DJ, Dixon PM. A study of sub-occlusal secondary dentine thickness in overgrown equine cheek teeth. Vet J 2012;193:53–7.
[9] Kempson SA, Davidson ME, Dacre IT. The effect of three types of rasps on the occlusal surface of equine cheek teeth: a scanning Electron microscopic study. J Vet Dent 2003;20:19–27.
[10] Weary DM, Niel L, Flower FC, Fraser D. Identifying and preventing pain in animals. Appl Anim Behav Sci 2006;100:64–76.
[11] Rollin B. Animal pain, scientific ideology, and the reappropriation of common sense. J Am Vet Med Assoc 1987;191:1222–6.
[12] Hansen B. Through a glass darkly: using behavior to assess pain. Semin Vet Med Surg (Small Anim) 1997;12:61–74.
[13] Bath G. Management of pain in production animals. Appl Anim Behav Sci 1998;59:147–56.
[14] Lesimple C, Hausberger M. How accurate are we at assessing others' well-being? The example of welfare assessment in horses. Front Psychol 2014;5:21.
[15] Grint NJ, Murrell JC, Whay HR. Investigating the opinions of donkey owners and veterinary surgeons towards pain and analgesia in donkeys. Equine Vet Educ 2015;27:365–71.
[16] Price J, Marques JM, Welsh EM, Waran NK. Pilot epidemiological study of attitudes towards pain in horses. Vet Rec 2002;151:570–5.
[17] Berman L, Hartwell G. Diagnosis. In: Cohen S, Hargreaves K, editors. Pathways of the pulp. 9th ed. Philadelphia: Mosby Elsevier; 2006. p. 21–3.
[18] Dixon PM, Barakzai SZ, Collins NM, Yates J. Equine idiopathic cheek teeth fractures: Part 3: a hospital-based survey of 68 referred horses (1999–2005). Equine Vet J 2007;39:327–32.
[19] Cook WR, Kibler M. Behavioural assessment of pain in 66 horses, with and without a bit. Equine Vet Educ 2018. in press.
[20] Jonckheer-Sheehy VS, Delesalle CJ, van den Belt AJM, Van den Boom R. Bad behavior or a physical problem? rearing in a Dutch warmblood mare. J Vet Behav 2012;7:380–5.
[21] Fureix C, Menguy H, Hausberger M. Partners with bad temper: reject or cure? A study of chronic pain and aggression in horses. PLoS One 2010;5:e12434.
[22] McDonnell SM. Practical review of self-mutilation in horses. Anim Reprod Sci 2008;107:219–28.
[23] Gleerup KB, Forkman B, Lindegaard C, Andersen PH. An equine pain face. Vet Anaesth Analg 2014;42:103–14.
[24] Dyson S, Berger JM, Ellis AD, Mullard J. Can the presence of musculoskeletal pain be determined from the facial expressions of ridden horses (FEReq)? J Vet Behav 2017;19:78–89.
[25] van Loon JP, Van Dierendonck MC. Monitoring acute equine visceral pain with the equine utrecht university scale for composite pain assessment (EQUUS-COMPASS) and the equine utrecht university scale for facial assessment of pain (EQUUS-FAP): a scale-construction study. Vet J 2015;206:356–64.
[26] van Loon JP, Van Dierendonck MC. Monitoring equine head-related pain with the equine utrecht university scale for facial assessment of pain (EQUUS-FAP). Vet J 2017;220:88–90.
[27] Dacre IT. Equine dental pathology. In: Baker GJ, Easley KJ, editors. Equine dentistry. 2nd ed. Edinburgh: Elsevier Saunders; 2005. p. 91–110.
[28] Horbal A, Reardon R, Liuti T, Dixon P. Evaluation of ex vivo restoration of carious equine maxillary cheek teeth infundibulae following debridement with dental drills and hedstrom files. Vet J 2017;230:30–5.
[29] Lundström T, Wattle O. Description of a technique for orthograde endodontic treatment of equine cheek teeth with apical infections. Equine Vet Educ 2016;28:641–52.
[30] Di Filippo PA, Vieira V, Rondon DA, Quirino CR. Effect of dental correction on fecal fiber length in horses. J Equine Vet Sci 2018;64:77–80.
[31] Johnson C, Williams J, Phillips C. Effect of routine dentistry on fecal fiber length in donkeys. J Equine Vet Sci 2017;57:41–5.

[32] Gunnarsdottir H, Van der Stede Y, De Vlamynck C, Muurling F, De Clercq D, van Loon G, et al. Hospital-based study of dental pathology and faecal particle size distribution in horses with large colon impaction. Vet J 2014;202:153–6.
[33] Ralston S, Foster D, Divers T, Hintz H. Effect of dental correction on feed digestibility in horses. Equine Vet J 2001;33:390–3.
[34] Carmalt JL, Townsend HG, Janzen ED, Cymbaluk NF. Effect of dental floating on weight gain, body condition score, feed digestibility, and fecal particle size in pregnant mares. J Am Vet Med Assoc 2004;225:1889–93.
[35] Zwirglmaier S, Remler HP, Senckenberg E, Fritz J, Stelzer P, Kienzle E. Effect of dental correction on voluntary hay intake, apparent digestibility of feed and faecal particle size in horse. J Anim Physiol Anim Nutr 2013;97:72–9.
[36] Mansmann RA, Currie MC, Correa MT, Sherman B, vom Orde K. Equine behavior Problems Around farriery: foot pain in 11 horses. J Equine Vet Sci 2011;31:44–8.
[37] Rice MK, Henry TJ. Standing intraoral extractions of cheek teeth aided by partial crown removal in 165 horses (2010–2016). Equine Vet J 2018;50:48–53.
[38] Vlaminck LE, Huys L, Maes D, Steenhaut ML, Gasthuys F. Use of a synthetic bone substitute to retard molariform tooth drift after maxillary tooth loss in ponies. Vet Surg 2006;35:589–95.
[39] Hielm-Björkman AK, Kuusela E, Liman A, Markkola A, Saarto E, Huttunen P, et al. Evaluation of methods for assessment of pain associated with chronic osteoarthritis in dogs. J Am Vet Med Assoc 2003;222:1552–8.
[40] Choi BC, Pak A. Peer reviewed: a catalog of biases in questionnaires. Prev Chronic Dis 2005;2:A13.