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Possible association of short-term complications and antimicrobial use in standing equine cheek tooth extractions 2018–2022

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Abstract

Background: Despite growing concerns about antimicrobial resistance, prophylactic antimicrobials continue to be routinely administered in many procedures, including dental extractions. Further evidence-based research is needed on whether their use influences post-operative complication rates.

Objectives: To identify risk factors for short-term complications, associations between complications and antimicrobial use as well as factors leading to antimicrobial use in equine (standing) cheek tooth extractions.

Study Design: Retrospective analysis of clinical records.

Methods: Data were extracted from records of horses undergoing cheek tooth extractions (2018–2022). Multi-variable logistic regression models examined associations between clinical variables and the occurrence of complications and antimicrobial use.

Results: Three hundred and five cases undergoing 447 dental extractions were included. Of these, 197 cases (64.6%) received antimicrobials. Complications occurred in 56 cases (18.4%); these were considered mild and transient in 39 cases (12.7%) and severe, requiring veterinary treatment, in 18 cases (5.6%). Occurrence of complications demonstrated an association with increased antimicrobial use (OR 2.69; CI 1.20–6.04; $p = 0.02$), presence of concurrent diseases (OR 4.32, CI 1.89–9.84; $p = 0.001$), extraction of mandibular teeth compared to maxillary teeth (OR 2.20; CI 1.14–4.23; $p = 0.018$), warmer seasons (OR 1.97; CI 1.03–3.76; $p = 0.04$) and the reason for extraction being either dental infection (OR 6.37; CI 2.39–16.97; $p < 0.001$) or dental fracture (OR 3.90; CI 1.53–9.91; $p = 0.004$) versus periodontal diseases. Antimicrobials were more frequently used when more than 2 teeth were extracted (OR 5.96; CI 2.26–15.70; $p < 0.001$), when dental infection was the reason for extraction (OR 3.75; CI 1.76–8.02; $p = 0.001$) or when the extraction was performed in warmer seasons (OR 1.96; CI 1.17–3.29; $p = 0.01$).

Conclusions: Complication rates were comparable to previous studies and in large numbers of horses antimicrobials were not administered, which did not result in higher

complication rates. Antimicrobials might be justified in horses suffering from concurrent diseases.

KEYWORDS
antibiotics, antimicrobial stewardship, concurrent diseases, dentistry, horse, oral surgery

1 | INTRODUCTION

Antimicrobial resistance (AMR) poses a major threat to human and veterinary health care, and veterinarians are strongly encouraged to critically reflect on the administration of antimicrobials in order to minimise AMR development and to ensure effective antimicrobial use in the future.

Furthermore, administration of antimicrobials is not without risk for the patient itself.[1] In horses, antimicrobial use has been associated with acute colitis,[2] neurological abnormalities[3] and other adverse effects.[4] In recent years, the use of prophylactic antimicrobials in equine elective procedures has been increasingly questioned. In elective arthroscopies, their use has not been shown to influence the incidence of postoperative joint infections.[5] Similarly, studies comparing complication rates in castrations found no positive impact of prophylactic antimicrobial administration.[1]

Oral dental extraction in the standing horse is considered the current gold standard[6] with fewer complications compared to other techniques.[7,8] Reported complication rates range from 6.6% to 18.4%,[9–12] causing more severe or long-term clinical problems in less than 1%–7.9%, with alveolar bone sequestration representing the most frequent one.[10] In healthy horses, perioperative antimicrobials were not associated with lower complications in standing oral cheek tooth extraction, but extraction method (minimally invasive transbuccal extraction) and age (younger horses) were significantly associated with the development of complications.[9] Other factors that influence complication rates are tooth position (mandibular)[10] and dental infections as the reason for extraction.[10,12] In horses undergoing dental extraction associated with sinusitis, the administration of antimicrobials showed no effect on complication rates or the likelihood of a successful outcome.[13]

As in human medicine,[14] in dogs[15] and in horses[16] dental extractions are accompanied by a transient bacteremia. While bacteremia has been associated with systemic complications in other species, for example, endocarditis in dogs,[17] the clinical relevance in horses remains unclear. Bacteremia might justify the use of perioperative antimicrobials in certain cases, for example, horses with pituitary pars intermedia dysfunction (PPID), as these horses might develop complications more often due to their compromised immune response. Furthermore, there are documented cases of severe and even fatal complications after dental extractions, for example, septic meningitis[18,19] or head and neck abcessation,[20] which might be a reason why some veterinarians chose to administer antimicrobials when extracting teeth. Thus, other factors that have not yet been investigated may have a greater impact on the risk of complications than the use of antimicrobials, for example, concurrent diseases like PPID.

To date, antimicrobials are still routinely used in equine dental extractions. Additionally, little is known about the factors that influence a clinician's decision-making to administer antimicrobials.

Therefore, the primary aim of this study was to identify risk factors for short-term complications in horses undergoing oral cheek tooth extraction with and without the use of antimicrobials. The second aim was to identify factors that led to the administration of prophylactic antimicrobial and to gain insight into the surgeon's decision-making processes.

2 | MATERIALS AND METHODS

Medical records of horses undergoing one or more cheek tooth extractions at a single equine clinic (first opinion and referral centre) between January 2018 and January 2022 were reviewed. Cases with clinical signs of sinusitis were excluded as well as all extractions of incisors, canines, wolves, and/or deciduous teeth and extractions that involved minimally invasive transbuccal extraction (MTEs) procedures (Figure 1). Information from clinical records of patients was included until hospital discharge as well as all information in cases of readmission during the study period.

Data collected from medical records included: patient signalment (age, breed, sex), reason for (diagnosis) and method of dental extraction, number of sessions (attempts at extraction), number of extracted

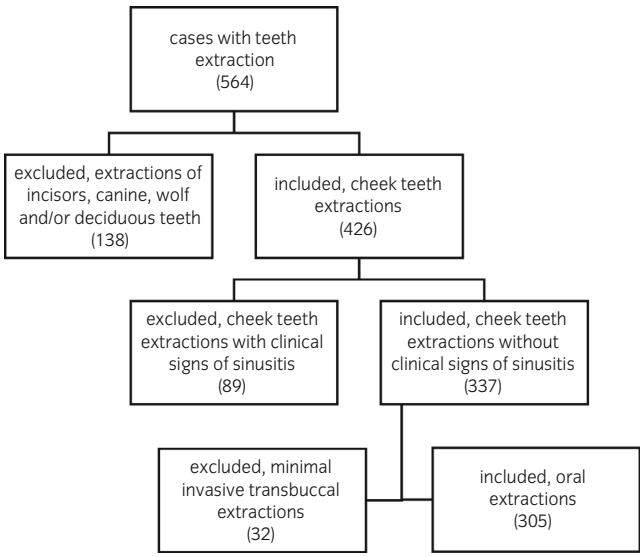

FIGURE 1 Flowchart showing the inclusion and exclusion of horses in this study, between January 2018 and January 2022.

teeth, triadan number of extracted tooth/teeth, known concurrent other diseases, length of hospitalisation, short-term complications (until discharge), administration of antimicrobials and other medications (non-steroidal anti-inflammatory drugs [NSAIDs], opioids, gastroprotectants, long term medications, e.g., pergolide). When performed, blood adrenocorticotropic hormone (ACTH) concentrations (pg/mL) were recorded.

In cases where antimicrobials were administered, the following parameters were recorded: antimicrobial drug used, the total duration of antimicrobial administration (during hospitalisation and after discharge), start of administration (pre-, peri-, post-operative, or when complications arose), if there was one or more changes in antimicrobial drug administered and reasons thereof.

Antimicrobial administration was based on the individual decision of the attending veterinarian and medical records rarely contained additional information on decision-making processes.

Reasons for extraction were divided into the following groups: (1) dental (apical or endodontic) infections, (2) tooth fractures without obvious evidence of apical infection, (3) periodontal disease, and (4) 'other' which included developmental disorders, neoplasia, and head shaking.

The classification of complications was adapted from a previous study[9] and is displayed in Table 1.

Routinely, dental extractions were performed in the standing, sedated horse using detomidine and butorphanol (intravenous, 0.01 mg/kg each, Domidine 10 mg/mL, Dechra; Butomidor 10 mg/mL, Richter Pharma), restrained in stocks. An intravenous catheter was placed for constant-rate infusion (CRI)-sedation with detomidine and butorphanol as well as intravenous crystalloid fluid administration (lactated Ringer's solution, Vetifundin, OÖG GmbH). Peri- and post-operative analgesia was provided by administration of 1.1 mg/kg flunixin meglumine (Niglumine 50 mg/mL, Vana) i.v. and local anaesthesia was performed using either a mandibular (extraoral, vertical approach[21]) or maxillary (extraperiorbital fat body insertion technique—EFBI[22]) nerve block with mepivacaine (3 mL / 100 kg bwt, Mepinaest purum 2%, Gebro Pharma).

3 | DATA ANALYSIS

All statistical analyses were performed using Stata v15.1 (StataCorp). Univariable associations were evaluated between all independent variables of interest and the two outcome variables (the presence of complications and antimicrobial use) separately using chi-square tests and univariable logistic regressions. For each outcome variable, a multivariable logistic regression model was built including all independent variables with p-value ≤0.2 from the univariable analyses. A stepwise backward elimination procedure was used to develop the two multivariable models with the level of significance set at 0.05. Potential two-by-two interactions between significant variables in the final models were further evaluated. Results of the two final logistic regression models were presented as odds ratios (ORs) with their respective 95% confidence intervals (CIs).

4 | RESULTS

A total of 305 horses undergoing 447 cheek tooth extractions (median 1 (1–2) extractions per horse) met the inclusion criteria and 5 clinicians, including 4 EVDC- or ECVS/ACVS-Diplomates, were involved in the extractions and peri-operative care of these horses. Horses' median age was 17.76 (11.48–23.73) years (ranging from 0.2 to 39.1 years). While horses age was not significantly associated with the risk of complications ($p = 0.3$), younger horses were more likely to receive antimicrobials than older horses (79% vs. 59.8%; $p = 0.03$) (Table 2).

The breed distribution of our study population reflected that of the general hospital population, with most horses being Warmblood (mixed) breeds (169; 55.4%), followed by ponies (69; 22.6%), other breeds (46; 15.1%) and Thoroughbred (mixed) breeds (21; 6.9%). One hundred and seventy-three horses were geldings (56.7%), 115 mares (37.7%) and 17 stallions (5.6%). Breed was not significantly associated with the risk of complications ($p = 0.9$) nor the use of antimicrobials

TABLE 1 Classification of post-operative short-term complications in 305 horses undergoing cheek teeth extraction.

	No complications (*N*)	Mild complications (*N*)	Severe complications (*N*)
Numbers total of affected horses (*N*)[a]	249	39	17
Fever (>38.5°C) (20)	None	No longer than 24 hours (11)	For >24 hours (9)
Colic (9)	No signs	Mild signs, required not more than 2 treatments (7)	Clinical signs required 3 or more treatments (2)
Facial paralysis (7)	No	Resolved without treatment (4)	Required treatment (3)
Sequestrum formation (15)	None	With previous bone involvement or sequestrum visible on pre-extraction radiographs (10)	Without previous bone involvement (5)
Orosinuidal/oronasal fistulas (6)	None	No treatment required (5)	Further treatment required, i.e., closure, flap techniques (1)
Others (14)	None	Haemorrhage, haematoma, root fragmentation (13)	Head and neck abscessation resulting in euthanasia (1)

[a]Horses may have suffered from more than one mild and/or severe complication.

TABLE 2 Frequency distribution of 305 horses and results of univariable analyses of associations between independent variables and the occurrence of short-term complications as well as antimicrobial administration.

		Occurrence of complications			Administration of antimicrobials		
Variable	**Categories**	**No (%)**	**Yes (%)**	***p*-value**	**No (%)**	**Yes (%)**	***p*-value**
Age (years)	≤9	46 (74.2)	16 (25.8)	0.3	13 (21.0)	49 (79.0)	**0.03**
	10–19	101 (83.5)	20 (16.5)		46 (38.0)	75 (62.0)	
	≥20	101 (82.8)	21 (17.2)		49 (40.2)	73 (59.8)	
Breed	Warmblood (mixed) breeds	135 (79.9)	34 (20.1)	0.9	64 (37.9)	105 (62.1)	0.3
	Thoroughbred (mixed) breeds	17 (81.0)	4 (19.1)		10 (47.6)	11 (52.4)	
	Pony	57 (82.6)	12 (17.4)		20 (29.0)	49 (71.0)	
	Other	39 (84.8)	7 (15.2)		14 (30.4)	32 (69.6)	
Sex	Mare	91 (79.1)	24 (20.9)	0.7	40 (34.8)	75 (65.2)	0.8
	Stallion	14 (82.3)	3 (17.7)		7 (41.2)	10 (58.8)	
	Gelding	143 (82.7)	30 (17.3)		61 (35.3)	112 (64.7)	
Duration of hospitalisation (days)	1–5	144 (94.1)	9 (5.9)	**<0.001**	74 (48.4)	79 (51.6)	**<0.001**
	≥6	104 (68.4)	48 (31.6)		34 (22.4)	118 (77.6)	
Reason for tooth extraction	Dental infection	48 (68.6)	22 (31.4)	**0.006**	15 (21.4)	55 (78.6)	**0.004**
	Tooth fracture	99 (81.1)	23 (18.9)		48 (39.3)	74 (60.7)	
	Periodontal disease	88 (89.8)	10 (10.2)		43 (43.9)	55 (56.1)	
	Other	13 (86.7)	2 (13.3)		2 (13.3)	13 (86.7)	
Extraction site	Maxillary	141 (86.5)	22 (13.5)	**0.01**	63 (38.7)	100 (61.3)	0.2
	Mandibular	107 (75.4)	35 (24.7)		45 (31.7)	97 (68.3)	
Extraction technique	Simple oral extraction	224 (83.0)	46 (17.0)	**0.04**	100 (37.0)	170 (63.0)	0.1
	Other techniques	24 (68.6)	11 (31.4)		8 (22.9)	27 (77.1)	
Total number of extracted cheek teeth	1	158 (81.4)	36 (18.6)	0.9	75 (38.7)	119 (61.3)	**0.01**
	2	56 (80.0)	14 (20.0)		27 (38.6)	43 (61.4)	
	≥3	34 (82.9)	7 (17.1)		6 (14.6)	35 (85.4)	
Number of sessions	1	212 (80.9)	50 (19.1)	0.7	97 (37.0)	165 (63.0)	0.1
	≥2	36 (83.7)	7 (16.3)		11 (25.6)	32 (74.4)	
Season	Warm (spring & summer)	115 (76.2)	36 (23.8)	**0.02**	43 (28.5)	108 (71.5)	**0.01**
	Cold (autumn & winter)	133 (86.4)	21 (13.6)		65 (42.2)	89 (57.8)	
Concurrent disease(s)	No	213 (83.9)	41 (16.1)	**0.01**	91 (35.8)	163 (64.2)	0.7
	Yes	35 (68.6)	16 (31.4)		17 (33.3)	34 (66.7)	

Note: *p*-values marked in bold represent statistically significant variables ($p \leq 0.05$).

($p = 0.3$). Similarly, sex did not influence the risk for complications ($p = 0.7$) nor the use of antimicrobials ($p = 0.9$) (Table 2).

The median duration of hospitalisation was 6.5 (3–8) days, ranging from 0 to 61 days, and longer duration of hospitalisation was associated with both the risk of complications ($p < 0.001$) and the use of antimicrobials ($p < 0.001$) (Table 2).

Short-term complications occurred in 56 horses (18.36%). In most horses (39; 12.70%) complications were classified as mild and transient, with little or no treatment required for resolution of clinical signs. Complications categorised as severe, indicating that additional treatment was required, occurred in 17 cases (5.57%). The group of horses in which antimicrobials were used had a complication rate of 24.37% (48/197), compared to 8.33% (9/108 cases) in the group without antimicrobials ($p = 0.001$).

Among the horses that received antimicrobials, only 17 cases (8.6%) were given the first dose several hours or days prior to the procedure, while in 3 cases (1.5%), the initial dose was given immediately before surgery. In most horses, the first dose of antimicrobials was administered the evening after the extraction (172 cases, 87.3%). In the study period, this was common practice as clinicians' primary concern was complications arising from post-operative contamination of the extraction site. There were 5 horses (2.6%) that did not receive antimicrobials initially, and antimicrobial treatment was started after surgery when complications occurred.

The median duration of antimicrobial administration was 5 (4–7) days. Horses that did not develop complications received antimicrobials for a significantly shorter period of time (5.8 days ± SD 3.0 [95% CI 5.3–6.3]) compared to those that did develop complications

(7.6 days ± SD 4.4 [95% CI 6.3–8.9]), ($p = 0.004$). The vast majority of horses were given trimethoprim-sulfadiazine (177/197 horses, 89.9%), while 10 horses received a combination of benzylpenicillin and gentamicin (5.1%), 5 horses received doxycycline (2.5%), 2 horses received marbofloxacin (1.0%), 2 horses received a combination of benzylpenicillin, gentamicin, and metronidazole (1.0%) and 1 horse received a combination of benzylpenicillin and metronidazole (0.5%).

NSAIDs were administered in all but 2 horses for a median duration of 4 (3–6) days. In the 2 horses that did not receive NSAIDs, methadone was provided in one case due to a history of chronic renal injury, and in the other case pain medication was not considered necessary due to a very loose 406. Similar to the duration of antimicrobials, NSAIDs administration was significantly shorter in horses that did not develop complications (4.4 days ± SD 2.9 [95% CI 4.0–4.7] vs. 7.7 days ± SD 6.8 [95% CI 5.9–9.5]; $p = 0.006$).

The reason for extraction was dental infection in 70 cases (23.0%), tooth fractures in 122 horses (40.0%), periodontal disease in 98 horses (32.1%), and other changes (developmental disorders or head shaking) in 15 horses (4.9%). The diagnosis affected the likelihood that complications occurred ($p = 0.006$), and also the clinician's decision to administer antimicrobials ($p = 0.004$, Table 2).

Complications were twice as likely to happen after removing a mandibular cheek tooth (24.7%) compared to a maxillary one (13.5%) ($p = 0.01$), there was no difference between maxillary and mandibular extractions in regard to antimicrobial use ($p = 0.2$) (Table 2).

The majority of cheek teeth (272, 89.2%) were removed by simple oral extraction. Twenty-nine horses (9.5%) required additional tooth sectioning, 3 teeth (1.0%) were extracted orally with the help of a screw, and 1 (0.3%) required surgical extraction. The extraction technique had a significant effect on the rate of complication ($p = 0.04$), as simple extractions had a complication rate of 17.0% compared to other, more invasive techniques with a risk for complications of 31.4%. Antimicrobial use was not associated with the extraction technique ($p = 0.1$) (Table 2).

Horses included in this study had one or more (up to 5; median 1 [1, 2]) cheek teeth removed in one or more sessions. Horses, in which more than 2 teeth were extracted, received antimicrobials significantly more often (61.3% vs. 85.4%; $p = 0.01$). The number of extracted teeth (1, 2 or more teeth) did not affect the complication rate ($p = 0.9$, Table 2).

The season that the horse was presented for tooth extraction affected the chances to develop complications and receive antimicrobials (Table 2). Extractions performed in warmer seasons, that is, spring and summer, had a higher risk of complication compared to those performed in colder seasons, that is, autumn and winter (23.8% vs. 13.6%; $p = 0.02$). Horses admitted during warmer seasons received antimicrobials more often compared to colder seasons (71.5% vs. 57.8%; $p = 0.01$). In 51 horses (16.4%) concurrent conditions were identified in the clinical records. Twenty-two horses had endocrine conditions such as PPID, 14 horses had gastrointestinal conditions, 8 horses had upper and lower airway diseases, and 7 horses had other conditions (e.g., orthopaedic diseases).

The presence of concurrent diseases significantly increased the risk of complications (31.4% vs. 16.1%; $p = 0.01$), but antimicrobials were not administered more commonly ($p = 0.7$) (Table 2). ACTH was measured in 36 horses; 20 horses had concentrations <50 pg/mL, 16 horses >50 pg/mL. Due to the sparsity of available data, this variable was not included in the final analysis.

In the final multivariable logistic regression analysis (Table 3) the use of antimicrobials remained significantly associated with complications (OR 2.69 [95% CI 1.20–6.04]; $p = 0.02$). Furthermore, when concurrent diseases were present, odds for complications increased (OR 4.32 [95% CI 1.89–9.84]; $p = 0.001$).

Mandibular tooth extraction increased the risk of complications compared to extraction of a maxillary cheek tooth (OR 2.20 [95% CI 1.14–4.23]; $p = 0.02$). Additionally, the reason for cheek tooth extraction remained significant in the multivariable model. Compared to periodontal disease, extractions due to dental infections had an increased risk of complications (OR 6.37 [95% CI 2.39–16.97]; $p < 0.001$) and fractured teeth increased risk (OR 3.98 [1.53–9.91]; $p = 0.004$). Other reasons for extraction (e.g., developmental disorders and neoplasia) did not increase the risk of complications compared to periodontal diseases (OR 1.88 [95% CI 0.33–10.52]; $p = 0.5$). Complications were more likely to occur in spring and summer compared to autumn and winter (OR 1.97 [95% CI 1.03–3.76]; $p = 0.04$).

In the final multivariable model exploring reasons for antimicrobial use (Table 4) the association between antimicrobial use and complications remained significant (OR 2.98 [95% CI 1.35–6.58]; $p = 0.007$). When more than 2 teeth were extracted, clinicians were more likely to administer antimicrobials (OR 5.96 [95% CI 2.26–15.70]; $p < 0.001$). Additionally, horses received antimicrobials more often if dental infection was the reason for extraction (OR 3.75 [95% CI 1.76–8.02]; $p = 0.001$), and more often if a fractured tooth was extracted (OR 1.53 [OR 0.85–2.78]; $p = 0.2$) compared to periodontal disease being the reason for extraction. Again, season played a role, as antimicrobials were administered twice as often during warmer seasons compared to colder ones (OR 1.96 [95% CI 1.17–3.29]; $p = 0.01$). Diagrams detailing occurrences of complications in perceived high-risk groups—based on uni- and multivariable analysis results—with and without the use of antimicrobials are provided as Figure S1.

5 | DISCUSSION

While mild and transient complications were encountered in every eighth case of cheek tooth extractions, complications serious enough to require treatment were infrequent in our study population. Different from a previous study,[9] we excluded cases of paranasal sinusitis and minimal invasive transbuccal extractions, as these conditions and extraction methods may contribute to complications unrelated to the tooth extraction itself. Additionally, antimicrobials in these cases may be administered for reasons other than the extraction.

The complication rate in our study is comparable to previous studies with complication rates ranging from 6.6% to 22%.[9–12] Also, the rate of more severe complications is similar to previously

TABLE 3 Results of the final multivariable logistic regression model evaluating the association between selected explanatory variables and the occurrence of short-term complications in the 305 study horses.

Variable	Categories	No.	Odds ratio	95% CI	*p*-value
Antimicrobial use	No	108	–[a]		
	Yes	197	2.69	1.20–6.04	0.02
Concurrent disease(s)	No	254	–		
	Yes	51	4.32	1.89–9.84	0.001
Extraction site	Maxillary	163	–		
	Mandibular	142	2.20	1.14–4.23	0.02
Reason for extraction	Periodontal disease	98	–		
	Dental infections	70	6.37	2.39–16.97	<0.001
	Fractures	122	3.90	1.53–9.91	0.004
	Other	15	1.88	0.33–10.52	0.5
Season	Cold	154	–		
	Warm	151	1.97	1.03–3.76	0.04

Abbreviation: CI, confidence interval.
[a]Reference category.

TABLE 4 Results of the final multivariable logistic regression model evaluating the association between selected explanatory variables and the administration of antimicrobials in the 305 study horses.

Variable	Categories	No[a]	Odds ratio	95% CI	*p*-value
Complications	No	249	–[a]		
	Yes	56	2.98	1.35–6.58	0.007
Number of extracted teeth	1 or 2	264	–		
	≥3	41	5.95	2.26–15.70	<0.001
Reason for extraction	Periodontal disease	98	–		
	Dental infection	70	3.75	1.76–8.02	0.001
	Fractures	122	1.53	0.85–2.78	0.2
	Other	15	6.58	1.35–32.09	0.02
Season	Cold	154	–		
	Warm	151	1.96	1.17–3.29	0.01

Abbreviation: CI, confidence interval.
[a]Reference category.

published data.[10] Unfortunately, complications were not uniformly defined across studies, which likely accounts for some differences. In order to promote comparability across studies, a major concern when clinical studies addressing the same topic have been published, we chose to categorise complications based on a previously published study.[9] This categorisation included both mild and severe complications. Some of these complications did not require further veterinary intervention to resolve. While there could be potential concerns about the clinical significance of these complications, we believe that even minor complications are perceived by veterinarians and owners as such and warrant investigation into whether they can be avoided by preventative treatments, for example, peri-operative antimicrobial administration.

Regarding the effect of antimicrobial administration on the occurrence of complications, a previous study found that whether or not antimicrobials were administered did not affect the rate of complications.[9] The results of this study show that we do not observe a reduction in complications when antimicrobials are administered but rather an increased occurrence of complications in cases that received antimicrobials. Since our medical records do not allow us to identify the specific reasons for antimicrobial administration in individual cases, these findings must be interpreted with caution.

In the vast majority of cases, antimicrobials were administered peri- and postoperatively and started before complications occurred. A possible reason why an increased occurrence of complications was seen in cases where antimicrobials were administered is that clinicians anticipated a greater risk in certain animals or groups of animals. This might have resulted in an increased number of horses receiving antimicrobials in higher risk groups (e.g., dental infection or younger age). Nevertheless, antimicrobial administration appeared to have limited or no effect on complication rates in these groups, which would support the results of a previous study.[9] However, it is also possible that in some of these cases, antimicrobial use might have prevented complications directly associated with the extraction or reduced the severity of complications.

Ultimately, this study showed that in large numbers of horses, including higher risk groups, horses did not receive antimicrobials and did not develop complications. Therefore, the preventative effect of

antimicrobial administration should be weighed carefully against its potential negative effects.

Further, antimicrobial use could have caused some of the recorded complications, as signs of colic were seen in some patients and have been reported as potential side effects[2] and their effect on gastrointestinal microbiota composition has also been well documented.[23] Next to reducing the risk for AMR development, this finding may advocate an even more cautious use of antimicrobials.

The vast majority of antimicrobials were started in the evening after the extraction. This was common practice at this clinic during the study period. We acknowledge that this protocol was not appropriate for surgical antimicrobial prophylaxis, as prophylactic antimicrobials should be administered 30–60 min prior to the start of surgery.[1,24] Ever since, antimicrobial policies have changed, and postoperative 'prophylactic' antimicrobial use is no longer allowed and/or practised.

The choice of antimicrobial drug was due to surgeons' preference. In the vast majority of cases, drugs in accordance with antimicrobial stewardship guidelines were used. Nevertheless, two cases received marbofloxacin, a drug considered as critically important antimicrobial (CIAs) by WHO.[25] Due to stewardship guidelines and national legislation, this practice has changed at our clinic, and CIAs are only used when sensitivity testing and clinical signs leave no other option.

The present study revealed an increased risk for complications with mandibular compared to maxillary cheek tooth extractions. This increased risk of developing post-extraction alveolar disorders (bone sequestration and/or infection) has already been reported for extraction of mandibular teeth, especially premolar teeth (Triadan 06, 07 and 08 s), possibly due to the proposed denser bone, poorer blood supply, and increased forces during extraction, compared to maxillary teeth.[10,12] It is unclear if these complications can possibly be prevented by antimicrobial administration, while complications were more commonly encountered; antimicrobials were not administered more frequently.

Also the positive correlation between dental infections and increased risk for complications, shown in this study, was reported previously,[10,11] probably due to infections of the adjacent bone and other surrounding tissues.[10] Antimicrobial administration in the presence of signs of infection makes sense from a clinical standpoint and is reflected by our results that show that these cases received antimicrobials more frequently. However, since complications were still encountered more commonly, the question remains if antimicrobial administration in cases of chronic infection changes the outcome and warrants further investigation.

In other species, bacteremia after dental extractions is rapidly cleared from systemic circulation by the endoreticular system within 10–20 min.[26] Townsend et al.[27] showed that in horses intravascular bacteria might still be present 60 min after extraction; however, without any further complications. The consequence of this transient bacteremia for the individual patient remains unclear at this point.[16] Based on our results and another study,[9] this bacteremia does not seem to justify the use of antimicrobials in healthy horses.

Interestingly, age was not associated with an increased risk for complications. This contradicts results from previous studies, where younger horses were more commonly affected by complications.[9,12] This difference might be due to an older study population (median age of 17.8 here, compared to 12.9–14.7 years in other study populations[9,12]) and a resulting lower number of younger horses, which precluded us from finding a significant association between younger age and complications.

To the authors' knowledge, the positive correlation between concurrent diseases and occurrence of complications has not been reported previously in cheek tooth extractions in horses or small animals. Nevertheless, the American Veterinary Dental College recommends antimicrobials to reduce bacteremia in animals that are immunocompromised, have underlying systemic disease, and/or when severe oral infection is present for small animal dental procedures.[28] As horses with concurrent diseases, for example, PPID, might be immunocompromised, the use of prophylactic antimicrobials is potentially justified but requires further investigation. On the other hand, horses suffering from chronic gastrointestinal conditions might be more prone to complications, that is, colic or diarrhoea, when antimicrobials are used, which advocates for an individualised approach when it comes to antimicrobial administration and presence of concurrent diseases.

The finding that complications are more common in the warmer seasons was surprising and has not been reported in the literature in regard to teeth extraction in horses, small animals, or humans to date. Few publications mention different seasonal effects on complications, but do not provide clear reasons for such correlations. Interestingly, but similarly without sufficient reason to explain this finding, antimicrobials were more frequently administered in spring and summer compared to autumn and winter.

Horses with complications received antimicrobials more often and for longer durations, and the same was true for NSAIDs. Decisions to use antimicrobials (longer) might have been influenced by cognitive factors.[1] As we know from human medicine, clinicians rarely have accurate expectations of the benefits and harms of treatments, screenings, and tests.[29] A so-called 'optimism bias' was identified, meaning clinicians more often underestimated harms and overestimated the benefits of a treatment.[29] In our context, clinicians might rather be concerned about the complications occurring when we do not administer antimicrobials than worry about the adverse effects. Underestimating the harm and overestimating the benefits of antimicrobial use might not only affect the specific patient but also have consequences in a larger one health context, that is, the development of AMR. Furthermore, a 'commission bias' describes the tendency towards an action rather than inaction, so clinicians might feel the need to be 'better safe than sorry' and decide to administer antimicrobials.[30] Perhaps both optimism and commission bias influenced the decision making of clinicians here, for example, by using antimicrobials more often when more than 2 teeth were extracted, although these horses did not develop complications more frequently. Using the results of this study, antimicrobial prescription practices were changed

at our hospital, and prophylactic antimicrobials are not used routinely in dental extractions any longer.

The retrospective design of this study represents a key limitation. Data were obtained from clinical records and it cannot be excluded that some clinical information, for example, very mild and transient complications, were not documented. Furthermore, the reasons for antimicrobial administration, when not part of a standard protocol, could not always be conclusively determined despite detailed medical records. A prospective study would be necessary to overcome this limitation.

Another limitation is the lack of long-term follow-up due to the institution's privacy protection policy; therefore, we might have missed complications that occurred after hospital discharge. However, a relatively long hospitalisation period, averaging nearly 7 days, likely allowed for the detection of most complications within the initial days following extraction. Furthermore, many cases involved long-term patients with regular re-check appointments. Combined with the likelihood that referring veterinary surgeons would have contacted the hospital in the event of complications, the number of undetected complications is likely low.

This study was conducted at a single equine hospital acting as both first opinion and referral centre. Although we were able to include a large number of horses, this study has typical limitations related to its single centre character. We adapted the classification of complications from a previous study[9] and this classification scheme may include some complications, for example, facial paralysis that can neither be prevented nor treated by antimicrobials, which is another limitation of this study. However, by assessing medical records carefully, we did exclude all complications that might have been present prior to tooth extraction (e.g., impaction colic being the reason for a dental exam). Ultimately, the retrospective nature did not allow us to conclusively identify cases where antimicrobial administration prevented or potentially even resulted in complications and a prospective, randomised clinical trial would be necessary to overcome this limitation.

The rate of mild complications was comparable to previous studies; severe complications were uncommon. In large numbers of horses, antimicrobials were not administered, which did not result in higher complication rates. Nevertheless, the use of antimicrobials might be justified in horses suffering from some concurrent diseases. Studies evaluating the benefit of antimicrobials in immunocompromised horses, for example, PPID patients, undergoing cheek tooth extractions are warranted. In the face of AMR, clinicians are challenged to use the slowly appearing evidence to critically reflect and reconsider their antimicrobial administration behaviour.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

Marlies Schnierer: Conceptualization; investigation; writing – original draft; writing – review and editing; visualization; data curation; project administration; resources; validation. **Omid Nekouei:** Writing – review and editing; methodology; formal analysis. **Lisa Christina Huber:** Writing – review and editing; conceptualization; data curation; investigation; resources. **Matthias Jehle:** Writing – review and editing; conceptualization; data curation; investigation; resources. **Nora Biermann:** Writing – review and editing; supervision; conceptualization; methodology; data curation; formal analysis; project administration; resources; validation.

DATA INTEGRITY STATEMENT

Marlies Schnierer and Nora Biermann had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

ETHICAL ANIMAL RESEARCH

Research ethics committee oversight not currently required by this journal: retrospective study of clinical records.

INFORMED CONSENT

Explicit owner informed consent for inclusion of their animals in this study was not obtained or required, as owners agreed to use of their patients' records for research in general.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/evj.14563.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in 'figshare', http://doi.org/10.6084/m9.figshare.28741223.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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